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CONTENTS.

	PAGE
Council and Officers	i-ii
General Notices	iv-vi
Personal Notes and Special Notices	vi-vii
The Present Position of Knock Testing Standardisation: Standard Fuels. By C. H. BARTON, M.A., A.I.C...	468
Engine Types and the C.F.R. Standard Engine. By C. H. SPRAKE	471
Methods of Test and Precautions to be Observed. By R. STANSFIELD, A.M.Inst.C.E.	476
The Funnel Meter as an Aid to Production. By NIELS MATHESON, M.Am.I.M. and M.E. ..	485
Small Well Production Problems. By A. H. CHAPMAN..	498
Empirical Formulæ for the Production Curves of Oil from Wells. By LAUNCELOT OWEN, A.R.S.M., A.R.C.S., D.I.C., M.Inst.M.M., F.G.S.	500
Decomposition of Ethylene by Heating under High Pressure. By H. I. WATERMAN and A. J. TULLENERS	506
Injection, Ignition and Combustion in High-Speed Heavy-Oil Engines. By S. J. DAVIES, Ph.D., M.Sc., and E. GIFFEN, M.Sc.	511
Current Petroleum Notes	515
Reviews	516

ABSTRACTS

	PAGE		PAGE
Geology	383A	Special Products	404A
Field Technology	386A	Refining and Refinery Plant.	405A
Crude Oil	390A	Cracking	408A
Gas	392A	Hydrogenation	411A
Motor Fuels	395A	Chemistry of Petroleum ..	413A
Kerosine	398A	Analysis and Testing ..	415A
Lubricants and Wax ..	399A	Anti-Detonation	417A
Fuel Oil	403A	Engines	420A
Fluxes and Asphalts.. ..	403A	Coal and Shale	422A

AUTHOR INDEX.

The numbers refer to the Abstract Number.

Alden, R. C., 971

Barnes, K. B., 951
Baron, C., 973
Barrere, C. A., 976, 987
Bendixen, N., 988
Bianchi, A. E., 1021
Boulanger, C., 973
Boyd, T. A., 972
Bradley, W. F., 1036
Brooks, B. T., 949
Brown, G. G., 970
Brown, L. S., 946
Bruun, J. H., 1030

Caldwell, L., 998
Castleman, R. A., 1040
Celite Corpn., 998
Chmelevsky, A., 978
Chorlton, A. E. L., 1037
Clark, G. L., 961
Conine, R. C., 991
Cowles, H. C., 960

Deppe, W. P., 1010
Deterding, Sir H. W. A., 974
Dickenson, H. C., 1032
Dubbs, C. P., 1001, 1002, 1007

Edeleanu, L., 998
Egloff, G., 959, 960, 962, 1000
Elkington, H. D., 1013, 1014, 1018
Esau, A., 1031
Eyoub, E., 950

Faught, C. B., 996
Ferris, S. W., 980
Fischer, F., 1025
Foster, A. L., 1033

Gas Light and Coke Co., 1019
Grant, D. W., 1003
Guardabassi, G., 1021

Hamilton, R. O., 998
Hanna, R. W., 1005, 1006
Harkness, R. B., 948
Haseman, W. P., 955
Hayes, H. R., 956
Henderson, L. M., 980
Hicks-Bruun, M. M., 1030
Holmes, W. K., 1011

I. G. Farbenind. A.-G., 983, 998, 1015, 1017

Johnson, J. Y., 992, 1015

Keane, A. E., 999
Kirschbraun, L., 1009
Kremer, M., 1028

Larson, S. A., 1042
Le Grain, R., 973
Lindsly, B. E., 965
Link, T. A., 945
Löffler, J. E., 1016
Logan, W. B., 984
Louis, — —, 978

Mallbe, A., 989
Maruhn, J., 1020
Meyer, K., 1025
Millener, E. D., 967
Moody, C. L., 947
Moore, T. V., 954
Morgan, J. G. Y. D., 998

N. V. de Bataafsche Petr. Mij., 1013, 1014, 1018
Neeley, A. W., 979
Nelson, E. F., 959, 960, 962
Nelson, W. L., 1026

Otto, F. C., 977

Pfau, G., 976, 987
Podbielniak, W. J., 964
Pohjanpalo, E., 1043
Pollock, R. T., 1006

Rector, N. K., 989
Renaudie, — —, 989
Rice, F. O., 1023

Ridgway, C. M., 995
Robinson, C. I., 975
Rutherford, J. T., 966

Schnauffer, K., 1034
Schlater, K. C., 966
Semet-Solvay Eng. Co., 960
Shankland, R. V., 979
Sheldon, H. W., 1004
Sieber, W. T., 1029
Sillers, D. A., 957
Slater, E. O., 1027
Smith, H. A., 961
Soc. d'Etudes Scientifiques et d'Enterprises Industrielles, 994
Staley, F. R., 963
Standard Oil Co., 997, 1005, 1006
Standard Oil Development Co., 975, 982
Stegeman, G., 1024
Stratford, W. M., 985
Sullivan, F. W., 979
Summers, L. L., 1010
Swanson, P. F., 1035

Taber, G. H., 1012
Texas Co., 984, 985
Thayer, V. B., 1024
Truesdell, P., 959, 960, 982
Tübben, L., 1020

Universal Oil Products Co., 1000-1002, 1007, 1008

Vacuum Oil Co., 1004
Voorhees, V., 979

Withrow, L., 972
Woodruff, G., 953
Wylde, H. D., 954
Wyszinski, O. C., 952

Ziegenhain, W. T., 961

SYMPOSIUM ON SALT DOMES.

A few copies of the complete Symposium on Salt Domes, including the discussion and the geophysical papers, in one complete volume are available at 10s. 6d. each.

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The Fund is raised by voluntary annual subscriptions, donations, and bequests, and all contributions should be sent to the Secretary of the Institution at Aldine House, Bedford Street, London, W.C. 2. The Fund is administered by the Council through the Benevolent Fund Committee, and all applications in connection therewith must be made on a special form which can be obtained from the Secretary of the Institution.

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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Mr. J. Berteloot has left Persia and is now in France.

Mr. J. T. Guthrie is home from Persia.

Mr. G. W. Halse has returned to Venezuela.

Mr. G. Heseldin is home from Iraq.

Lieutenant-Colonel R. H. T. Jobson is in Sweden.

Commander H. V. Lavington has left Ecuador and is now in Trinidad.

Mr. P. N. D. Porter has left Holland for Sumatra, D.E.I.

Mr. J. T. Warde is home from Venezuela.

The Secretary would be glad to hear of the whereabouts of the following members: C. A. Bauduin, J. D. Bing, N. M. Brodie, E. H. Crush, L. B. Holloway, C. E. Jobling, H. Leslie Little, Nand Lal Pasi, E. C. Scott, W. E. Shepherd, C. M. Stoney, John C. Templeton, R. K. Van Sickle, F. E. G. Watson and S. S. Webb-Bowen.

DINNER CLUB.

The attention of members is drawn to the Dinner Club of the Institution. This Club holds informal dinners after each General Meeting of the Institution and members may invite guests. Those desiring to receive notice of these dinners are requested to inform the Secretary of the Institution.

THIRTEENTH ANNUAL DINNER.

THE THIRTEENTH ANNUAL DINNER of the Institution of Petroleum Technologists will be held at the Connaught Rooms, London, on October 9th, 1931.

SMALL ADVERTISEMENTS.

In future the advertisement columns of the Journal will be open for the inclusion of small prepaid advertisements, such as Situations Vacant and Wanted, Patents for Sale and Miscellaneous, at a charge of 1s. 0d. per line of seven words (minimum 4s. 0d.). A charge of 1s. 0d. will be made for the use of a box number. Matter for insertion should be in the hands of the Associate Editor not later than the 12th of the month in which it is desired that the advertisement should appear.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE ONE HUNDRED AND THIRTY-SIXTH GENERAL MEETING of the Institution of Petroleum Technologists was held on Tuesday, May 12th, 1931, at the House of the Royal Society of Arts, John Street, Adelphi, London, Mr. J. KEWLEY (President) in the Chair.

The Secretary read the names of the candidates nominated for election and the following list of members elected :—

As Members.—Arthur Clark Atwater, Cyril Henry Barton, Frans M. G. Cochius, Leslie Francis Elsby, Leonard Gowen Gabriel.

As Transference to Member.—Geoffrey Barrow.

As Associate Members.—Cedric Michael Bolton, Albert Ernest Hewitt Edwin Malcolm Shipman, Norman Edward Wood.

As Transference to Associate Member.—Henry Ernest Tester.

As Student.—Douglas Weston Burgess.

The SECRETARY also announced that nominations for Council should be in his hands not later than November 30th, 1931.

THE PRESIDENT said that, as the paper which was to have been read on "The Dilution Theory of Detonation" had been postponed until next Session at the request of the author, Messrs. C. H. Barton, C. H. Sprake and R. Stansfield had kindly agreed to present a résumé of the work done to date on the subject of the knock rating of motor fuels. In this country a separate Standardization Sub-Committee had been set up to deal with the subject, as also in the United States, and co-operation between the two bodies had been effected.

The subject would be dealt with by the three authors separately in three parts. The first author, Mr. Barton, would deal with the subject of Standard Fuels, pointing out how the need for Standard Fuels arose and what had been decided upon. Mr. Sprake would then deal with the subject of the Standard Engine, describing the various types of engine and pointing out why one particular type had been selected; finally, Mr. Stansfield would undertake the exposition of the most difficult part of the problem: the method of using the standard engine or the standardization of the method of test when everything else had been settled.

The following papers were then read :—

The Present Position of Knock Testing Standardization. Standard Fuels.

By C. H. BARTON, M.A., A.I.C. (Member).

There are two principal methods in use for expressing the knock rating or tendency to detonate of a gasoline. By the first method, the rating is expressed in terms of an engine variable, such as the engine speed or the compression ratio at which a standard intensity of detonation occurs. This method will probably be eventually displaced, at any rate for all but research purposes, by the second method, which consists in expressing the knock rating in terms of the composition of a mixture of two hydrocarbon fuels, one of high and the other of low anti-knock value, the mixture giving the same degree of detonation as the unknown fuel when tested under the same conditions in the engine.

The second method of expressing knock ratings, which may be called the "matching method," has the obvious advantage over the first method in that the units employed are the same for all engines, and are independent of the engines. Consequently the method of reporting results in terms of equivalent mixtures of standard fuels is coming into universal use and has been adopted by the American Co-operative Fuel Research Committee in U.S.A. and by the Sub-Committee on Knock Rating of the Institution of Petroleum Technologists.

For expressing knock ratings in this way, two fuels are necessary, one lower in knock rating than the worst knocking fuel which has to be examined, and the other higher in knock rating than the best fuel which has to be tested against the standards. It is unsatisfactory to employ two gasolines as absolute standards, owing to the impossibility of defining them exactly and of ensuring continuity of supply. In addition, the composition of such fuels may undergo small changes owing to evaporation in storage. For these reasons, the American and English Committees have decided to use pure substances as standard fuels. In practice these fuels are used as absolute standards for calibrating sub-standard fuels and the latter are actually employed for direct comparison against unknown fuels.

Normal heptane appears to be the only material, apart from diethyl ether, of low anti-knock value which is obtainable in adequate quantities for use as a standard fuel, and this substance has been adopted for this purpose. Heptane is prepared from

Jeffrey pine oil by distillation. The product so obtained is about 99 per cent. pure. The properties of the pure substance are :—

B.Pt. at 760 mm.	98·4° C.
$d\,\frac{20}{4}$	0·6836
Refractive Index $n\,\frac{20}{D}$	1·38777

Ether is less satisfactory than heptane as a standard fuel because it is too volatile to be easily handled in engine work, and also because it is not a hydrocarbon.

For a high anti-knock standard there is the choice of several possible materials, namely, benzene, toluene, aniline and other aromatic amines, and iso-octane. The first two are well known and can be readily obtained in the pure state for a few shillings per gallon. There is little to choose between benzene and toluene as standards ; they both have a very high anti-knock value, but the purity of benzene may be more readily verified than that of toluene by means of a setting point determination. Aniline and the other amines are open to the objection that they are not hydrocarbons and they are also known to produce tarry deposits in the combustion spaces of engines. Iso-octane, or 2-2-4 trimethyl pentane was first made synthetically in quantity by Dr. Graham Edgar,[1] who proposed its use as standard fuel for knock-testing. Iso-octane is prepared by treating tertiary butyl alcohol with sulphuric acid and hydrogenating the resulting octene. Its properties are :—

B.Pt. at 760 mm.	99·3° C.
$d\,\frac{20}{20}$	0·6914
Refractive index, $n\,\frac{20}{D}$	1·3921

Iso-octane does not possess as high an anti-knock value as benzene or toluene, but it is higher in this respect than any commercial gasoline at present being marketed. The chief advantages of iso-octane over benzene and toluene appear to be :—

(1) Octane blends show a smaller drop in knock rating with increase in cylinder temperature than is the case with blends of benzene or toluene.

(2) The knock rating of mixtures rich in benzene increases very rapidly with increase in benzene content, much more rapidly

[1] *Ind. Eng. Chem.*, 1927, **19**, 145.

than that of the corresponding octane mixtures. Hence experimental errors due to inaccuracy of blending become more serious in the case of benzene mixtures at high concentration.

(3) Fuels containing high proportions of benzene are more liable to give pre-ignition than octane mixtures.

It has been agreed by the American and English Committees that knock ratings of gasolines shall be expressed in terms of the equivalent iso-octane-heptane blends, the results being given as "octane numbers." An "octane number" is the percentage by volume of iso-octane in the mixture with normal heptane, each constituent being measured separately before mixing. Supplies of pure heptane and octane may be obtained from the American Committee at $25 per U.S. gallon. The quality of these standard fuels is guaranteed by the U.S. Bureau of Standards for engine test work to within 1 octane number.

For evaluating fuels having knock-ratings higher than that of iso-octane, the tentative proposal of the Committees is that pure benzene shall be used together with iso-octane. This recommendation may appear to be somewhat inconsistent with objections against benzene previously mentioned. The fact is, however, that knock ratings of practically all volatile fuels which are likely to be used in the near future are included in the octane-heptane scale, with the exception of alcohol mixtures incorporating more than about 30 per cent. alcohol and fuels containing very high proportions of benzole and similar materials. For evaluating these exceptional fuels, iso-octane and benzene mixtures will be provisionally employed, but the proportions of pure benzene required in the standard fuel mixtures will be very much lower than would be necessary if pure benzene and normal heptane were used as standard fuel. The point of the compromise is that pure benzene and its inconvenient behaviour are excluded from the standard fuel until we are faced with the problem of determining the knock ratings of fuels higher in anti-knock value than iso-octane. In this connection it is worth pointing out that the fuels in common use for gasoline engines have octane numbers between 50 and 80. A difference of one octane number corresponds with the effect of the addition to a fuel of low anti-knock value of about 2 per cent. pure benzene for low octane numbers and with about 1 per cent. benzene for high octane numbers.

With regard to the accuracy of measurement of octane numbers, agreement within one octane number is usually obtained in tests carried out on the same fuels on different days in the same engine working under specified conditions. At present some testing engines of the same type and make may in extreme cases give differences of two or three octane numbers on the same fuel; whilst in engines

of different type the octane numbers obtained for the same fuel may disagree by 10 units. The necessity for a single standard reference engine for knock testing is, therefore, apparent. In the present state of our knowledge of the phenomenon of detonation, it is impossible to say which engine is "correct" in the case of a number of engines giving divergent results on the same fuel; in fact, it cannot be said with certainty that, in carrying out knock rating determinations we are observing identically the same phenomenon in every type of engine. Unfortunately, in the type of engine most important practically, namely, the multi-cylinder engine, the experimental difficulties attending the determination of accurate knock ratings of fuels have not yet been overcome.

Engine Types and the C.F.R. Standard Engine.

By C. H. SPRAKE.

A VERY large number of engines have been made for the purpose of testing fuels for knock rating, but the number of types still being manufactured is rapidly falling with the realisation that the building of such engines is a matter for experts. Even with full knowledge of the difficulties involved, it is now understood that different types of engine may not necessarily give identical results, and this has led to the introduction of a standard engine.

Among the earliest designs used for knock testing were the Ricardo E.35 engine and the Delco air-cooled engine. The former has remained substantially unaltered since its inception in 1919, while the latter has undergone extensive changes and, in its present form, is designated as the S.30 engine.

Fig. 1 shows the E.35 design. The cylinder has a bore of 4½ in. and a stroke of 8 in., giving a capacity of nearly 2100 c.c. The engine is of the overhead valve type with two inlet and three exhaust valves, and the compression ratio can be varied, while the engine is running, between 3·7 and 8 to 1. Ignition is from two synchronised plugs by coil. Arrangements are made for adding a known amount of heat to the inlet air, and the water jacket temperature and the engine speed can be controlled as desired over a wide range.

Power output is measured very accurately by means of a cradled dynamometer, the torque being in proportion to the difference between the dead load added to the dynamometer arm, and the reading of the spring balance to which the arm and dead weights

are coupled. Fuel consumptions can be taken when desired by measuring the time of flow through double conical ended measuring vessels, these being calibrated between points in the narrow inlet and outlet necks where the fuel passes at a high rate.

The S.30 engine (Fig. 2) has a bore of 2½ in. and a stroke of 5 in., giving a capacity of about 400 c.c., and is coupled by two Tex-V belts to a synchronous motor. This arrangement ensures that the speed of the engine is always constant independent of the output, and thus avoids the use of a hand operated speed control. When a non-standard working speed is required for special tests the pulley ratios are altered to suit.

The engine has overhead valves, one inlet and one exhaust, and is cooled evaporatively. The usual jacket temperature is 212° F., and for this distilled water is used, pumped through the jacket spaces at a high rate to avoid any stagnant places. Vapour from the coolant is condensed in a reflux condenser and returned to the system. When other jacket temperatures are required above 212° F., a mixture of ethylene glycol and water is used having the necessary boiling point. This mixture is obtained by the temporary use of a fractionating column in place of the reflux condenser.

Ignition is from a single plug by coil, and a neon-tube indicator is fitted to the crankshaft so that the ignition setting can be read when the engine is running.

No inlet air heater is provided, and the fuel is fed from one of two bowls which are mounted on screws so that the fuel head on the jet can be adjusted to give any necessary air-fuel ratio. Fuel consumptions are rarely required in connection with knock testing, and no ready means for determining these is provided.

The engine is arranged so that the maximum compression ratio can be altered in stages, when the plant is at rest, by inserting or removing shims from the joint between the cylinder and the crankcase. The maximum ratio available is approx. 7½ to 1. A fine adjustment is fitted to the throttle valve so that this can be opened or closed very gradually to control the intensity of knock.

The cylinder head is adapted to take a bouncing pin indicator for measurement of the knock.

Fig. 3 shows the Armstrong fuel testing plant which has a bore of 2⅞ in. and a stroke of 3½ in. giving a capacity of about 370 c.c. This is available either with a fixed field dynamo used merely for absorbing power, or with a cradled dynamometer with which accurate power output measurements can be made. The engine is of the side-by-side valve type, and the maximum compression ratio of the standard head is 8 to 1. The compression ratio is altered by raising or lowering a 1½ in. bore plug in an extension of the combustion space above the piston.

This sliding plug is fitted with a diaphragm at its lower end to take a bouncing pin indicator.

The engine speed is controlled by hand through a shunt regulator. Ignition is from a single plug by coil, and the plug boss is well jacketted to avoid overheating.

The carburettor has a four-way feed system, one branch being used for running up, and the other three to take standard fuel blends and the sample under test.

These three branches are coupled to flowmeters of the submerged orifice type to enable changes in the rate of feed to be observed, although the exact feed rate must be determined by calibration for each fuel used when this is required.

The inlet air is heated electrically to any desired temperature, and the temperature indicated by means of a mercury thermometer inserted in a bend to keep the bulb clear of heater radiation and fuel blow-back effects.

The standard cooling system is divided into two parts, the cylinder head being cooled separately from the jacket, and with a simple alteration an evaporative system similar to that in use on the S.30 engine may be employed for high temperature tests.

Fig. 4 shows the present design of the engine which is being developed as a standard knock testing unit by the Co-operative Fuel Research Committee of the Society of Automotive Engineers, and with which the Knock-Rating Sub-Committee of the Institution of Petroleum Technologists is co-operating.

Like the E.35 engine this is of the overhead valve type with variable compression ranging from 4 to 1 up to 12 to 1. The bore is 3¼ in. and the stroke 4½ in., giving 610 c.c. capacity. The cylinder body and the head are cast in one piece to avoid local hot spots which might lead to pre-ignitions at the higher ratios.

The main and crankshaft bearings are very liberally proportioned to minimise wear, and the crankshaft is extremely rigid. Ignition is now from a special magneto arranged with trailing poles so that the flux density is independent of advance, but coil ignition may be used as an alternative if required. One plug is fitted, and a neon tube indicator shows the spark advance. The valve gear push rods are mounted in an ingenious manner on a swinging link, so that the valve clearances remain constant for any compression ratio, and at the same time change of ratio alters the ignition advance so that this is always maintained at the correct value for the ratio in use.

The cylinder head is arranged to take a bouncing pin indicator.

The engine output may be absorbed by any suitable form of generator, but the use of a synchronous motor is recommended to eliminate the need for hand speed control.

The carburettor illustrated on the C.F.R. engine is a special type devised by Mr. E. M. Dodds of the Laboratory Department of Anglo-American Oil Co. It is at present being subjected to exhaustive tests by members of the C.F.R. Committee with a view to its adoption as the standard instrument for use on the C.F.R. engine. The carburettor can be fitted with either two or four float bowls, each supplied with a sight glass, and arranged symmetrically round a vertical induction pipe of short length passing under the float bowls to the horizontal position, for bolting direct to the intake valve flange of engine. A horizontal jet is supplied from either of the float bowls at will by means of selector cocks. A shroud pipe supplying bleed air is fitted over the jet, and the mixture strength can be varied by admitting more or less air through the shroud pipe, thus varying the depression on the actual jet orifice. Adjustable bleed air cocks are fitted to each float bowl, and they are brought into or out of operation simultaneously with the fuel selector cocks. Thus a number of fuels can be set at max. knock mixture strength, and the engine can be switched from one to the other without further adjustment.

This carburettor has been found to give very constant air-fuel ratios at different throttle settings and speeds without any adjustment maintaining a constant comp-ratio.

The following values have been obtained on the same carburettor adjustment :—

16°	Throttle	600	r.p.m.	14·92–1	Air	Fuel	Ratio
16°	,,	1200	,,	14·95–1	,,	,,	,,
Full	,,	1200	,,	14·93–1	,,	,,	,,

An advantage of the four supplies is that the engine can be brought to equilibrium on one fuel, and the sample under test can be run between two samples, the octane numbers of which are known with the other three supplies. The value of the sample under test is thus quickly obtained with minimum consumption of reference fuels. An extremely fine sub-division of the fuel spray is also obtained which should assist towards elimination of inlet air heating. Whether air heating will be necessary or not is to be determined by tests already in progress in America.

The need for a reference standard fuel testing engine is shown very clearly by Fig. 5.

The curves given are the octane numbers for given percentages of pure benzene in a straight run spirit of average No. 1 distillation characteristics. One curve was taken from an E.35 engine and the other from an Armstrong engine. It will be seen that, at the lower end of the scale, there is a difference of as much as 7½ octane numbers in the ratings given to the straight run fuel, and that the

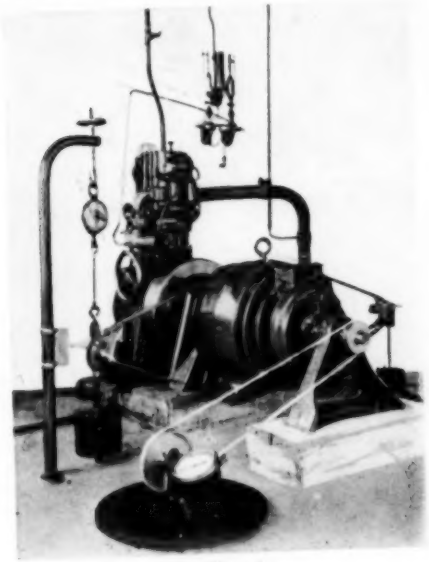

FIG. 1.

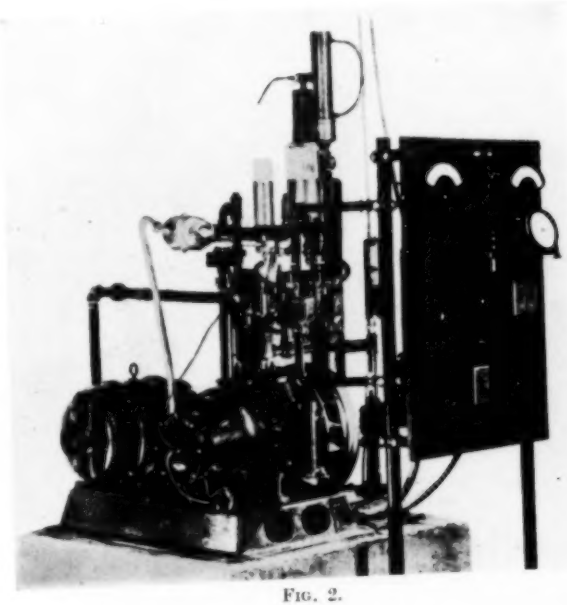

FIG. 2.

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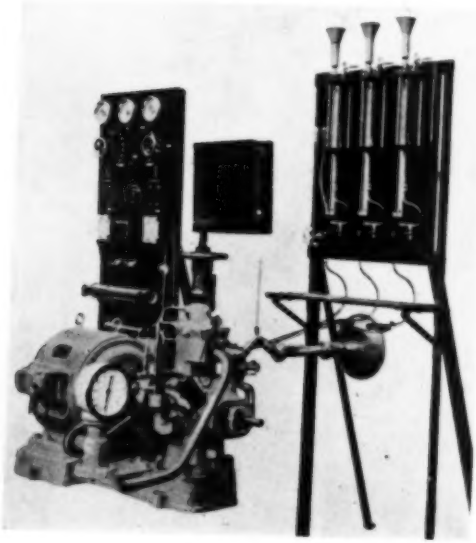

FIG. 3.

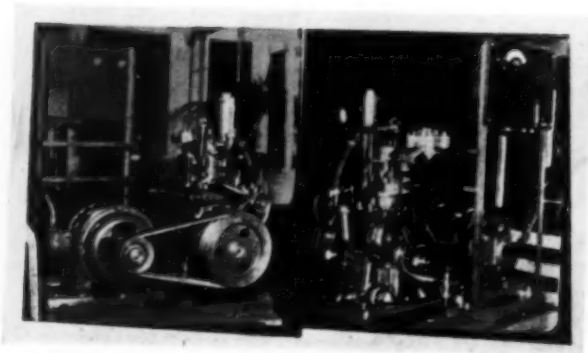

FIG. 4.

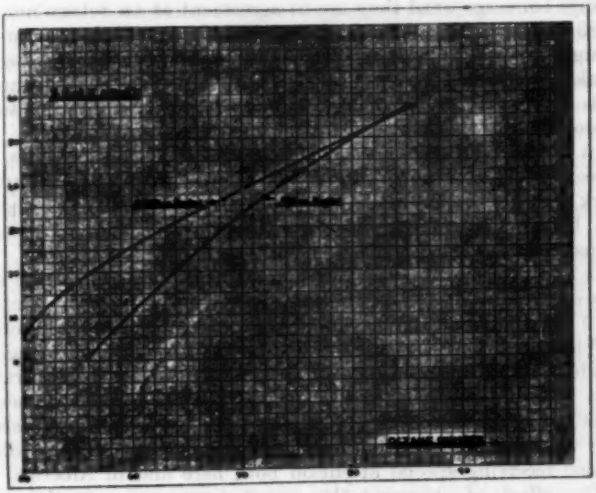

FIG. 5.

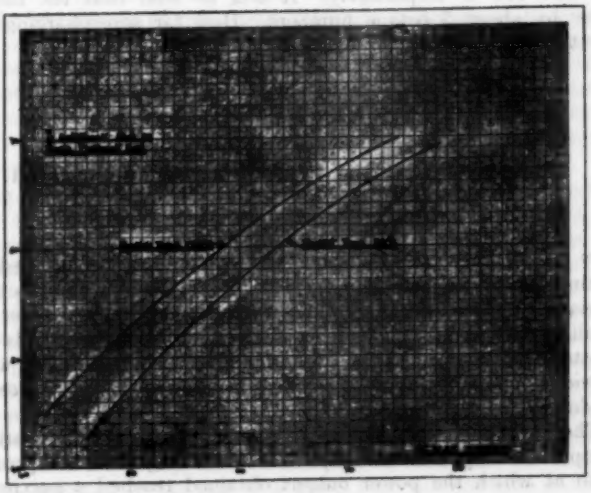

FIG. 6.

ratings converge until they are in agreement at an octane number of 83. Had a different pair of materials been substituted for the straight run spirit and benzene the relation between the two engines would have been different, and the band width for the full range of fuels in general use is much too large for any calibration to be made between the two designs.

In the cases of the Armstrong, S.30 and the C.F.R. engines, the agreement is very much closer, but is still not perfect. Further work is in hand to determine to what extent these different engines can be made to give the same results on any fuels by suitable adjustment of the operating conditions.

It is obvious that, since two different types of test engine may give different results when unlike fuels (as regards chemical composition) are compared, similar differences will be met with in practice.

When aviation fuels have to be tested for air cooled engines, it is found that it is necessary at least to raise the jacket temperature to a value of the order of 130° to 150° C., and, in some cases, to raise the engine speed as well, if the standard testing units are to give values in good relation to practice. This aspect of the problem is also receiving special attention both here and in America.

The effect of changing the jacket temperature is shown on Fig. 6, which shows the octane numbers for blends of a pro-knock and an anti-knock spirit determined at jacket temperatures of 50° and 175° C. respectively. It will be seen that the ratings differ by about 5 octane numbers. How far supercharging will affect ratings has not, so far, been studied.

Methods of Test and Precautions to be Observed.

By R. Stansfield, A.M.Inst.C.E. (Member).

It has already been indicated that the method now used for stating the knock rating of fuels is to find the blend of octane/heptane or benzene/octane which matches the sample under the conditions of test. It is, of course, permissible to use calibrated substandards instead of the expensive standards for routine work, *provided that the calibration has been made under the same engine conditions.*

The earliest determinations of knock rating made in variable compression engines were directed to the finding of the compression ratio at which the power output obtained reached a maximum, this value being known as the Highest Useful Compression Ratio.

It was soon found that different engines gave different H.U.C.R.'s on a given fuel, and attempts were then made to correlate results by determining the change of H.U.C.R. between that for the sample and that of a standard reference fuel, or by determining the ratio of the H.U.C.R. of the sample and of the reference fuel.

Neither of these methods proved to be really satisfactory.

At the same time the Delco engine, used with the Midgely bouncing pin was being used to determine the amount of standard anti-knock required to be added to the sample under test to make it equal to a given standard fuel. This method was good in that it introduced the principle of matching, but it was imperfect because it did not take into account the fact that two fuels of the same initial value might require different amounts of anti-knock agent to bring them up to a given value.

Difficulties in the interpretation of results persisted for many years because these variables were only imperfectly understood.

There was also a sharp division of opinion regarding the relative merits of testing in an engine with variable compression, always working at full throttle, and in a high ratio engine in which the knock intensity was controlled by reducing the throttle opening.

Closer co-operation between laboratories using different engines and methods has led to a very large measure of agreement as regards the essentials for proper testing.

The importance of using pure reference materials as standards, and of calibrating fuels against these by direct matching is now generally agreed. Except as regards experimental error it is immaterial whether the matching be done by determination of the compression ratio at which maximum power output is obtained, or by use of the bouncing pin, the latter giving more exact repeat values.

Fig. 7 shows the bouncing pin indicator as used with an electrolytic cell and alternatively with a special knock meter. When the engine knock occurs the high pressure wave travelling across the cylinder strikes a thin steel diaphragm, and this kicks upwards a light pin resting on its upper surface. The movement of the pin lifts the lower of a pair of contacts against the upper contact, and then the pair travel further upwards against a spring loaded stop plunger. The intensity of knock determines the time during which the contact is maintained. The contacts are included in an electrical circuit embodying either an electrolytic cell, a heater element enclosing a thermo couple attached to a recording instrument, or to a suitably damped milliameter, and thus the amount of gas collected in the cell in a given time (usually one minute), or the reading of the meter, indicates the degree of knock.

With this instrument it is only necessary to find the blend of standards which gives the same knock instrument reading as the sample under test, and this may be done either by direct matching

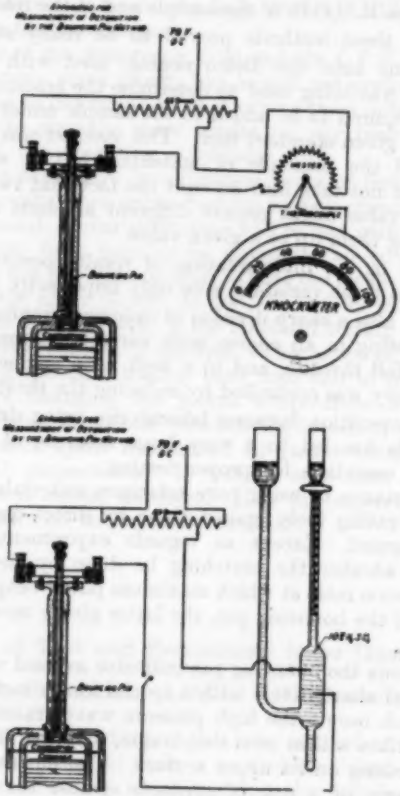

FIG. 7.

by trial, or by bracketting the sample between two slightly different standard blends and interpolating readings to obtain the required test value.

A definite standard of knock intensity, within fairly broad limits, is maintained for each test, and the necessary adjustments to obtain this depend on the type of engine in use. The final

method of bouncing pin adjustment for the C.F.R. engine has not yet been decided, but it is expected that details will be available shortly.

A further method of knock measurement was described at the S.A.E. meeting in January by Huf of The Atlantic Refinery, and depends on the use of a microphone coupled to a valve amplifier. This shows actual noise developed by the knock, and is thus a measure of what is heard by the car user. The published curves show that the output meter changes in reading by about 10 per cent. for an addition of 10 per cent. of benzole to the fuel under test when used under knocking conditions.

Tests made on a modification of this method for the Knock-Rating Sub-Committee of the Institution of Petroleum Technologists have shown that it can be made to give as much as a 30 per cent. change of output meter reading for a 5 per cent. change of benzole content. This gives a sensitivity equal to that of the bouncing pin. It is not anticipated, however, that the electrical audiometer will supersede the bouncing pin in engines adapted to use the latter, largely on account of its much higher cost. If, in its further development, it fulfils its present promise, it should be a very useful instrument in conjunction with testing large engines which cannot be used with the bouncing pin, and also for the measurement of knock in individual cylinders of multi-cylinder engines, and for the examination of knock at much lower intensities than can be dealt with by other methods.

When a variable compression engine is used, tests are always made at full throttle, and in the case of the S.30 design it is now suggested that the throttling used to control knock in lieu of varying the compression shall not be such as to reduce the air flow to the cylinder by more than 20 per cent. below the full throttle value, any necessary alterations being made by adjusting shims.

The effect of engine jacket temperature has already been shown, and control is provided so that this can be regulated to, say, $\pm$ 1° F., unless the pump circulated evaporative system is fitted, in which case no hand control is required.

Heavy carbon deposits in the combustion space have a similar effect to altering the jacket temperature, and it is therefore necessary to decarbonise shortly before important tests, such as sub-standard calibrations, are made. The engine should then be run for a few hours to obtain steady conditions in the combustion space.

The control of inlet air temperature is not yet standardised, but since some laboratories have to test in an atmospheric temperature up to 120° F. in summer, and others at temperatures not much above 45° to 50° F. in winter, it seems that this will be necessary,

and in many cases arrangements are already made for the inlet air to the engine to be heated to a standard temperature.

A further necessary control is that of mixture strength. It is known that either very weak or very strong mixtures reduce knock, and the method now recognised is to adjust the fuel supply so that the knock obtained is the maximum for the compression ratio or throttle opening at which the engine is set. This adjustment agrees fairly closely with the mixture strength for maximum power output, although there are minor exceptions.

As regards the degree of knock at which it is advisable to make tests, the variable compression engine used by an audibility method allowing only moderate knock is probably the nearest to the practical conditions under which a car user assesses his fuel. Unfortunately the audibility method is not sufficiently accurate unless specially trained observers of long experience are available.

When the H.U.C.R. method of determining the point of maximum power output is used in small engines, or, alternatively, the bouncing pin indicator, the degree of knock required is heavy. At present there is no solution of this difficulty, but work is in progress both here and in America with the object of improving the bouncing pin indicator, and it is possible that this may make the use of lighter knock intensities practicable for test purposes.

At the same time it should be mentioned that it is only in extreme cases, not coming within ordinary practice, that tests made with heavy knock give appreciably different ratings from those made with a lighter knock.

As regard speed control, this also is important. When the engine is coupled to a synchronous motor the speed is held constant, otherwise the same care must be exercised to keep speed constant as is necessary for the other controllable variables.

The position as regards the testing of aviation fuels is not so well advanced. Testing at high jacket temperatures, either by the H.U.C.R. method or with the bouncing pin, may be the solution, but there is evidence that failures in aero engines due to the use of knocking fuels arise from temperature effects. This has led Heron of the U.S. Air Force to adopt a thermocouple built into a partly heat insulated plug screwed into the engine cylinder, and to note the rise in temperature when knock commences as a measure of knock rating. Similar tests are also being made here on a 2-litre engine and are to be extended to include high temperature cooling.

Summarising.—There is now a standard fuel testing engine available for reference, the C.F.R. engine. A tentative standard operating technique has been laid down for its use, and this is to be modified from time to time as may be found necessary.

It is probable that certain existing engines may be calibrated against the C.F.R., and, in some cases, their operating conditions adjusted so that the results obtained are substantially the same.

All fuels should be rated in octane numbers determined either in a C.F.R. engine or in a calibrated alternative type.

No small part of the progress made towards standardisation is due to investigation of the various discrepancies which have arisen from the use of various types of engines and different operating conditions, and such work should of course continue.

DISCUSSION.

The President remarked that the meeting would agree that they had had a very clear and precise exposé of the present position. The three speakers were prepared to answer any questions which the meeting put to them; he suggested that instead of having a formal discussion the speakers answered each question as it was put.

With regard to the choice of iso-octane, he said that this substance could be regarded as a temporary standard. During the last few years a great deal of work had been done in the United States in synthesising new hydrocarbons in such quantities that their behaviour could be examined in engines. The results were very interesting. This work had mostly been done by Lovell, Campbell and Boyd, who had examined a large number of hydrocarbons which they had prepared, some of which had been found very much better than the iso-octane. For example, they had made a 3-3-4-4 tetramethyl hexane which had a beautifully symmetrical molecule and which had an anti-knock rating—expressed on a certain scale—of 29, whereas Edgar's iso-octane had only had a rating of 17, that of normal pentane being taken as 0. He, therefore, considered it quite possible that in future years methods of synthesising hydrocarbons of even greater anti-knock value might be devised, so that the necessity for using benzene for the higher portions of the scale might be overcome.

Dr. F. B. Thole said that the three speakers had dealt with the respective sections of the paper so clearly and thoroughly that there was little to add at the moment, although the developments of this work were being actively studied both in this country and abroad.

He wished to ask whether there were any objections to using heptane and lead tetraethyl as the pro-knock and anti-knock standards, thereby eliminating the expensive octane.

He would also be interested to learn what effect the fluctuations in atmospheric temperature, pressure, and humidity had on the octane

number rating of a petrol, especially as regards ratings recorded by an engine in this country and a similar engine in, say, Persia or Borneo.

Mr. C. H. Barton, in answer to the first point, said that when the anti-knock rating of mixtures of lead tetraethyl with heptane was plotted against the percentage of lead tetraethyl, a curve was obtained of which the first part was practically a straight line. Over that part of the curve the use of lead with heptane would be perfectly satisfactory, but there came a point where, so to speak, a ceiling was reached after which further additions of lead had a very much diminished effect on the anti-knock value. If, therefore, lead were used in heptane, the investigator was committed to employing a second standard fuel.

Mr. Stansfield, also in reply, stated that he did not know of much work on the humidity question, but such evidence as was available showed that in certain cases a difference of two to three octane numbers could be made between normal English humidity and tropical humidity. That was too much, and steps might have to be taken to cut it down if it was shown to affect the fuels in use. Heron, in the United States, used a dehydrator in the form of a large bottle in the engine suction line filled with a drying agent through which the air was passed before it reached the cylinder; as far as the speaker knew, however, this was merely a precautionary measure and used without actual evidence that the humidity had affected the knock ratings.

Mr. W. G. Adam inquired whether any work had been done on the use of such bodies as the xylenes, ethyl-benzene, trimethyl-benzene and general substituted benzenes in place of octane. These could all be readily obtained or synthesised.

Mr. Barton replied that a little work had been done on ethyl-benzene, which he believed had an even higher anti-knock value than toluene and xylene, but which he was almost certain suffered from the same defect as benzene and toluene: a relatively large fall in anti-knock value when the temperature was raised. He thought that naphthalene had a very low anti-knock value; it certainly had when mixed in small proportions with gasoline. It had been proposed to use 0·5 per cent. naphthalene as a dope, but in such proportions it had no appreciable effect at all.

Mr. Adam said that he thought naphthalene had a very high anti-knock value.

The President answered that naphthalene was reputed to have a high anti-knock value. He pointed out that its low solubility in gasoline and its tendency to settle out and block carburettor jets were distinct disadvantages.

Ricardo had examined xylene years ago, and had found that its anti-knock value was a little better than that of benzene, but not as good as that of toluene. There was, however, difficulty in getting any of the xylenes pure.

Mr. Adam remarked that a practically pure xylene could be obtained in the form of what was known as "two-degrees xylene" at a few shillings per gallon.

The President remarked that he did not think that in any case xylene had any advantage over benzene.

Mr. W. A. Whatmough stated that he had used naphthalene in engine tests, and had known the throttle to stick wide open and the engine to be stopped by a solid block of separated naphthalene. It was therefore an extremely difficult substance to use in an engine test.

Mr. A. T. Wilford asked whether, apart from questions of humidity, any corrections were made for temperature. He and his colleagues had found in testing multicylinder engines that a better correlation of results from day to day was obtained if temperature corrections were made. They had not actually taken humidity readings; they worked in a shop that was not uniformly heated and where therefore the temperature might vary from 5° to 10° C. over a period of weeks; this appeared to make a difference.

Mr. R. Stansfield replied that the effect of inlet air temperature on relative anti-knock values was measurable but that, so far, opinion was divided on the extent to which it was necessary to correct for temperature. Some workers maintained the air inlet temperature constant and others allowed it to take its course and vary with the external air temperature. The C.F.R. Committee were doing experimental work on this question. Opinion was tending towards the necessity for controlling temperature.

Dr. F. H. Garner remarked that one of the questions raised in the discussion was the choice of iso-octane and heptane as primary standards for knock-rating determinations. Unfortunately, in the petroleum industry there was a very large number of instances where instruments and methods of tests differed in various countries. In the determination of viscosities, for example, different instruments and temperatures of test were used in various countries, rendering the interconversion of viscosity determinations in different countries a matter of some difficulty. It was, however, possible with this new test to adopt throughout the whole world the same method for expressing and determining knock ratings.

In view of the high cost of octane and heptane it would be interesting to have from the speakers some information as regards the provision

of less expensive reference fuels than octane and heptane, calibrated in terms of octane and heptane, which were actually available for the determination of knock ratings of various motor spirits.

Mr. C. H. Sprake replied that he and his colleagues worked with sub-standard fuels which were calibrated in terms of octane and heptane, and were known as the A and B reference fuels; one of them gave from 50 to 68 octane value and the other from 68 to about 84. These fuels were calibrated carefully with varying additions of tetraethyl lead against octane and heptane at various temperatures, so that in testing a fuel they actually got a match of tetraethyl lead in the substandard fuel against the fuel under test which gave them their octane number. These reference fuels had been adopted by the American Fuel Research Committee as secondary standards and were obtainable from the Standard Oil Development Co. by anyone who wished to use them. They were carefully prepared and were similar in distillation range, and were stored in high-pressure cylinders, so that there was no loss by evaporation. Octane and heptane were very seldom used; reliance being placed upon the calibrated reference fuels.

Mr. T. R. H. Garrett enquired what was meant by "a difference of 2½ octane numbers" in the relation to humidity of fuels in England and in the tropics, as the relative humidity of England would on an average lie about midway between the relative humidities of East Borneo and the dry zone in Burma, both in the tropics. He suggested that in any statement of the difference of octane numbers the humidity should be included; it seemed almost more important than the temperature.

Mr. R. Stansfield, in answer, stated that tests had been made with air containing water vapour equal to 12 per cent. of the fuel by weight, and containing water vapour equal to 47 per cent. of the fuel by weight. In each case the air/water vapour supply was heated to 120° F. before entering the engine. A large number of fuels had been tested, generally without showing any difference, but the two giving the biggest difference in rating altered about 2½ octane numbers over that range.

The President then moved a hearty vote of thanks to the three speakers who, as he said, had so kindly stepped into the breach and helped the Institution that evening. He need not compliment them on the quality of the paper: it was sufficiently obvious, in view of the fact that a large audience had had so few questions to ask, that the subject had been put forward in a very able and concise way.

The vote of thanks was carried unanimously.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

TRINIDAD BRANCH.

A General Meeting of the Trinidad Branch of the Institution of Petroleum Technologists was held at the Apex Club, Fyzabad, on October 29th, 1930, when the Chair was taken by Mr. A. Frank Dabell. The following paper was read :—

The Funnel Meter as an Aid to Production.

By Niels Matheson, M.Am.I.M.&M.E. (Member).

It is now generally agreed that in the lenticular producing sands of Trinidad oil is forced into the well by gas pressure. There is little or no hydrostatic or volumetric control.

It is clear, therefore, that each lenticle contains a certain amount of oil and gas under a certain formational pressure. Some of the gas is in liquid form, while some may be in a free state lying above the oil.

The amount of gas energy stored in formational oil is in proportion to its pressure, and every barrel of oil will produce a definite quantity of gas when reduced to atmospheric pressure.

The properties of oil under formational pressure have already been very ably dealt with in a previous paper by Mr. Scott, and it is not proposed to deal with them further except to emphasize the fact that under these conditions oil is less viscous and, therefore, flows more easily through the sand; it retains a greater proportion of the lighter hydrocarbons, is of lighter gravity, and the bubbles of gas in the pores of the sand are smaller, pass more easily and give less resistance to the movement of oil through the sand.

When a well is drilled into such a lenticle and the mud is of sufficient weight to balance or exceed the formational pressure, there is no negative differential allowing the oil to flow into the well. When, however, the mud column is reduced in weight either by swabbing, bailing or displacing with water, the pressure on the face of the sands is reduced and the gas absorbed in the oil expands and displaces oil into the well. The gas entering the well and expanding further to the surface carries oil with it. In an efficiently designed flow string it is probable that the mixture is in the form of bubbles of gas in a body of oil at the bottom of the string, while at the top it is in the form of globules of oil in a body of gas.

If the differential pressure in the sands (*i.e.*, the difference in the pressure at the face of the sand and the pressure at a point outside the immediate influence of the well) is small, as it is under pressure control, the gas moves slowly towards the well carrying the oil with it. If this differential is great, as it is under initial open flow conditions, the gas having less frictional resistance to overcome moves faster than the oil and finding its way through the more porous pathways "channels" and leaves oil behind.

Let us consider the ordinary soda water bottle. Here we have a receptacle charged with water and CO_2 under pressure. No gas is visible in the water as it has been absorbed under pressure. The moment the cap is released, gas bubbles are seen to form, and these increase in volume in proportion to their submergence. At the beginning, because of the rapid expansion to atmospheric pressure, there is proportionately so much gas that the velocity in the neck is high and a certain amount of water is ejected. Finally, however, the water, having given up all energy due to gas pressure, remains in the bottle and is "dead."

If we take a syphon charged under exactly the same conditions, we can regulate the decrease in pressure and consequently the expansion of the gas, and with this factor, together with the better designed neck (or flow string), practically the whole amount of water is ejected. In other words, the energy stored in the water has been made to do a greater amount of work.

It is not possible to calculate the percentage of recovery from a well. It will be noticed that the production decline curve closely follows the pressure decline curve, and when the latter drops to zero oil production is very low, although a considerable quantity of oil is still left in the sands.

Instances of wells which have produced gas long after the oil flow has ceased have been known. It is suggested that these cases show that the majority of the gas channelled in the early life of the well, and taking its easiest path (upwards to the top of the sand and then laterally to the well) has left the oil banked up in the sands, and when the flow by gravity becomes balanced by the frictional resistance to flow, the oil is left in the position shown in Fig. 1.

As the formational pressure tends to gain equilibrium with the atmosphere small quantities of gas are still given off, though the channels are so open that they have the same effect as too large a flow string with a large amount of slippage, hence no oil is produced.

One cannot control the original formational conditions of energy and resistance, but one can to a large extent control the efficiency of the expulsion of the oil into the well and its lift to the surface.

It is rather the energy contained in the compressed and absorbed gas than that in the oil which is exhausted, and the efficiency of production methods is best judged by the proportion of oil and gas produced—i.e., the gas/oil ratio.

Beaning back a well to increase the pressure on the sands considerably reduces the expansion of the gas during its travel through the sands and, therefore, its speed of travel is reduced and there is less tendency to "bypass." Hence a larger proportion of oil is expelled by the gas and a lower gas/oil ratio results.

By decreasing this gas/oil ratio total recovery must be increased, although a temporary drop in rate of production usually follows such a decrease. This deferred production is generally made up

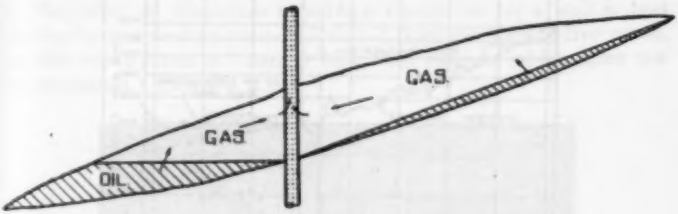

FIG. 1.

SHOWING PROBABLE DISPOSITION OF "DEAD" OIL IN EXHAUSTED LENTICLE.

in a very short time, because there is usually a considerable increase in daily production following such a change in back pressure (Fig. 2).

By further beaning down we reach a point when the gas/oil ratio begins to increase with a corresponding decrease in oil production. This is due to the reduced velocity in the flow string with an attendant increase of slippage of the oil back through the gas. Velocity can then be increased by tubing the well and thus decreasing the area of the flow string. Obviously then, wells which are tubed at the commencement of their life can be flowed with a smaller gas/oil ratio and therefore their ultimate production is increased.

The difficulties of clearing the mud (particularly if bearing barytes weighing sometimes as much as 130 lbs. per cubic foot) sometimes do not allow of this, but with modern tubing blow-out preventers, the snubbing of tubing under high pressure is a comparatively simple matter.

Optimum gas/oil ratios can only be determined by balancing physical factors against economic conditions. An economic rate

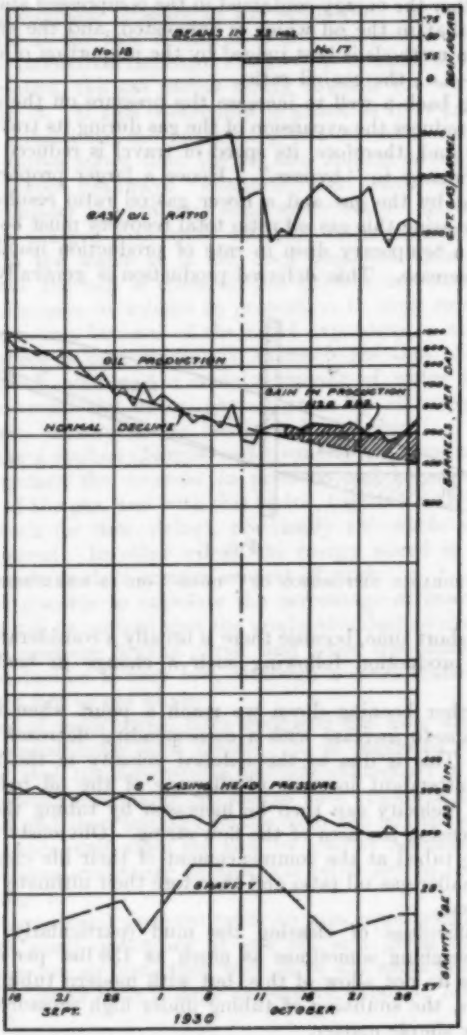

FIG. 2.

WELL "A," PALO SECO, SHOWING EFFECT OF BACK PRESSURE ON DECLINE.

of production often does not allow utilization of gas energy to its fullest extent. This is particularly so in the case of small producing wells which are on the programme for deepening to other and more prolific sands.

The changes in gas/oil ratios immediately following bean changes are not always a true indication of the general trend. In studying decline curves the slope of the curve is of as much importance to us as its elevation. In the same way the slope of the gas/oil ratio curve is as important as its elevation.

It is therefore essential that complete graphic records are kept of every known factor of the well. Careful study of the trend of such curves often brings to light some factor affecting production which the ordinary record of figures does not show.

The effect of alteration in surface conditions on a well is best shown by the decline curve calculated from the cumulative curve, as this curve forms a "danger line," the slope of which must not be increased. (See Fig 2.)

FIG. 3.

SHOWING CURVED FLOW LINE FROM FALSE DERRICK FLOOR (SNUBBED IN BY METHOD SHOWN IN FIG. 6).

It is advisable to have the flow tank as close to the well as possible. The author is in favour of having all flow lines coming out of the top of the flow string and down into the tank. When there is no danger of sand-cutting the flow line can be curved to advantage. (Fig. 3.) It is asking a lot to expect gas to blow bubbles of oil up a pipe and then round one or more right angle corners before passing through the bean.

A pressure gauge set on the down stream side of the bean will indicate conditions of surging more clearly than do the flow string gauge or the tank evidence.

The tank must, of course, be gas tight (unless a separator is used), and it is convenient to have a 6-in. flange fitted to the dome to take a standard funnel meter.

In experimenting to find the optimum gas/oil ratio, it is first necessary to change the bean until surging is reduced to a minimum, and such changes should be very gradual.

FIG. 4.

SHOWING 6-IN. FUNNEL METER IN USE.

The gas quantity can now be measured; and, here again, we are not so much interested in quantities as in rates of production. A series of spot tests of short duration with the corresponding oil production rates is more accurate than a 24-hour gas quantity chart with a 24-hour dip.

This being so, a convenient method of measuring the gas rate is by the funnel meter.

Flowing temperature is first obtained together with the specific gravity. The latter is best done with a small type apparatus, where the time of a known volume of gas and the time of a similar volume of air passing through a small orifice is measured.

The specific gravity is then equal to :—

$$G = \left(\frac{t \text{ gas}}{t \text{ air}}\right)^2$$

where t=time in seconds.

Fig. 5 shows the funnel meter which is fitted in the 6 in. flange on the tank or separator, and is a form of orifice meter where a standard sized hole will pass a standard quantity of gas under static pressure, depending on temperature and specific gravity of the gas and the barometric pressure.

A one and a half million foot meter has 19–1½ in., 2–1 in., 2–¾ in., 2–½ in. and 2–¼ in holes fitted with rubber plugs.

Under standard conditions—*i.e.*, Temp. 70° F., Sp. Gr. 1·0, and barometer 29·2 in. with 4 in. water static pressure, the holes pass the following quantities of gas per hour :—

1½ in	hole	..	3600	cu. ft. per hour
1 in.	,,	..	1600	,, ,,
¾ in.	,,	..	900	,, ,,
½ in.	,,	..	400	,, ,,
¼ in.	,,	..	100	,, ,,

The head to be carried is measured by a " U " tube and is

$$H = 72{\cdot}6 \frac{B.\ G.}{T}$$

where H = Head in inches of water.
B = Barometric pressure in inches of mercury.
G = Specific gravity of gas, air being 1·0.
T = Absolute flowing gas temperature = temp. °F.+460.

Plugs are taken out or added until H is obtained. The number of holes open then give a direct reading of the quantity of gas per hour.

Having established a value for H, no further calculations are necessary unless the temperature and specific gravity of the gas vary to any great extent. The tests can, therefore, be made by a semi-skilled man.

Four tests of 15 minutes duration spread over the 24 hours will give a sufficiently accurate value for gas/oil ratio.

Different wells naturally have different optimum gas/oil ratios depending on formational conditions. As the work done by the gas in expanding is in two states : (1) expelling the oil into the well, and (2) lifting it to the surface, it is not possible to get any value for the efficiency of the latter stage unless bottom hole pressures and velocities can be measured. If this is done, either by means of a

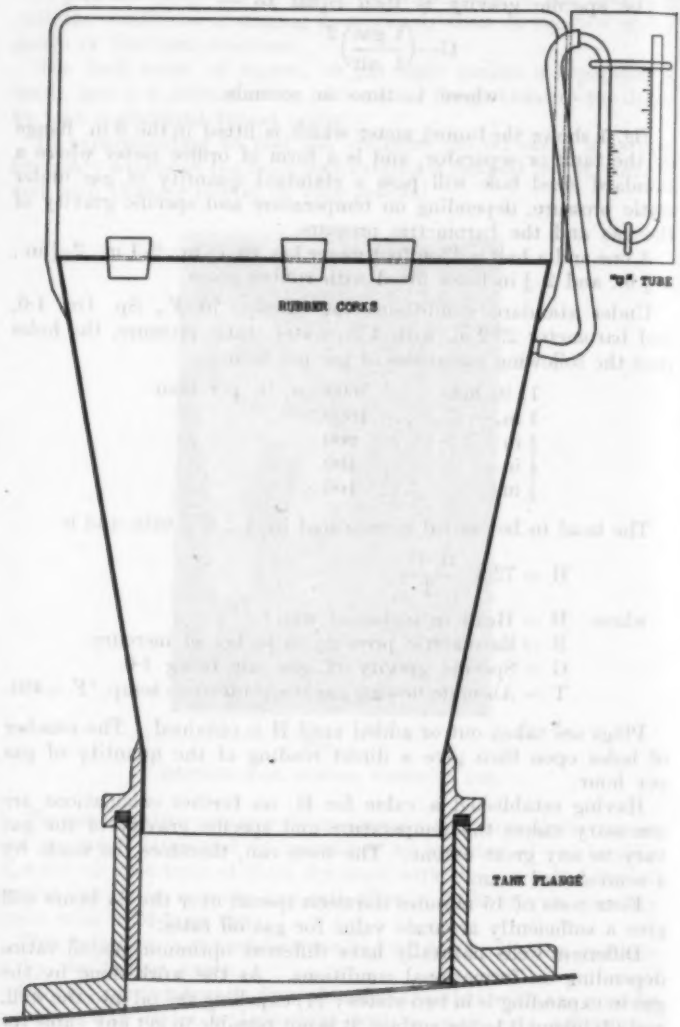

FIG. 5.

6-IN. (1½ MILLION CU. FT.) FUNNEL METER.

pressure bomb or an inverted compression tube, lift efficiency can be calculated, and figures for depth and size of tubing can be arrived at.

Any experimental work done with a view to finding out more about the underground conditions will be amply repaid by future increased production efficiency, and this work should form one of the most important sides of a producing company's activities.

DISCUSSION.

Mr. G. H. Scott said that the author's illustrations of the benefits of pressure control and conservation methods had been most illuminating.

The author had stated that the funnel meter was the most accurate method of gauging gas flows and was as accurate as a recording orifice meter. The speaker could not agree with this statement, as although the funnel meter was used for calibrating recording orifice meters it was only accurate where all leaks were excluded and where the requisite conditions of flow existed. Furthermore, even if the individual gas measurements at intervals were accurate it did not ensure that the gas flows between these intervals were at an equivalent rate. A well flowing by heads or flowing irregularly will always give false figures of daily flow as calculated by the funnel meter.

He (the speaker) suggested to the author the use of semi-logarithmic graph paper for giving more clearly the effects of change in production methods.

Mr. C. E. Capito said he did not agree with leaving commercial oil in the upper sands and running down to the lower sands because they would give double the production. Who was going to have that top oil; was it going to be left for future generations? If so, they required proper protection.

He was inclined to agree with Mr. Scott regarding the use of gas charts on most wells; they were the only true record of the amount of gas which had actually been produced. Slight variation of a bean might make large differences in gas/oil ratios and a gas meter was certainly the best way of recording results unless their production man was prepared to spend a long time at each well with the funnel meter.

Mr. W. J. C. Cooke said that what struck him most was the simplicity in operation and design of the apparatus the author mentioned. It was a very great asset to have a cheap apparatus that can, as he told them, almost be used by the layman.

Some time ago the speaker tried very similar methods of checking the gas/oil ratios, and on a cursory examination of the apparatus there that night, he wondered how the funnel meter and tank would fare in the event of a gas head occurring while it was in use. It then appeared to him, however, that so long as the corks were put in lightly, they would be ejected before much pressure was exerted on the tank.

In their "field made" meter, a heavy ring having a suitable manometer connection was fitted to the thief hole housing, but instead of the perforated plate and corks used in the funnel meter, single orifice plates were laid on top of this ring, and the outlet holes gradually diminished in size until a suitable pressure had been built up. The weight of those plates was such that in the event of a gas blow they would be forced off their seats before the pressure inside the tank could endanger the roof. He also used a "U" tube for measuring the pressure, but in that case it was fitted to a separate stand which tilted it at an angle and kerosine was used as the fluid instead of water, and thus more accurate readings were obtained.

Mr. A. J. Ruthven Murray stated that there was one question he would like to ask, that was with reference to the writer's statement that "The difficulties of clearing the mud (particularly bearing barytes weighing sometimes as much as 130 lbs. per cubic foot) sometimes do not allow of this, but with modern tubing blow-out preventers, the snubbing of tubing under pressure is a comparatively simple matter." Most of them had read how this was done, but he would like to know if the writer had any experience of altering the tubing level or snubbing tubing when the well was heaving, or again, whether he could tell them of any satisfactory way to control the flow of oil when doing that dirty job.

The Chairman (Mr. A. Frank Dabell), in closing the discussion, said that whilst separators and orifice meters gave more generous data in the matter of the gas/oil ratio they were cumbersome and expensive to instal. It might be plausibly argued that by their use their cost was soon repaid, but to-day the very existence of many operators was dependent upon ruthless reduction of expenditure.

Under that heading, anyone responsible for oilfield operation knew that scheme upon scheme was brought forward on the basis that the cost of their adoption would be returned over a comparatively short period and the figures submitted in support were sound, but their universal adoption would mean disaster in many cases for, generally, schemes arrived faster than the income could be earned to cover their cost.

If was generally known that the degree of restrictive control practised with flowing wells governed the course to be adopted for obtaining the greatest ultimate recovery, and the readiest guide to restrictive control was to be obtained from the measurement of gas released.

In the case of the funnel meter, they were offered an apparatus that could be made in any field workshop at the cost of a few shillings, and with that apparatus measurement of gas could be readily obtained within a few minutes of a well entering production.

The suggestion of Mr. Capito that sands should be exhausted serially added another phase to the paper, one which, if adopted, would have far-reaching economic effect.

Mr. N. Matheson, in replying, said that Mr. Scott had mentioned the use of semi-logarithmic paper for decline curves. This was normally used, but squared paper had been used to make the large illustrations necessary for that meeting.

He argued that it was better to use a 24-hour recording meter provided a 24-hour record of oil ratio could be simultaneously charged. On the other hand one had to bear two things in mind, the heavy cost of the meters and the large staff required to deal with the charts. The chart calculations were lengthy, whereas the funnel meter results could be quickly arrived at by a semi-skilled man with a fair degree of accuracy. This was an important point in these times of rigid economy.

Regarding Mr. Capito's remarks he thought that no company could afford to completely drain an oilsand, and what was more, no company here did. It was a question of economic production rather than ultimate recovery.

Mr. Cooke raised the question of safe back pressures on tanks. The funnel meter required only 4 in. of water and during heavy surges corks were very quickly displaced.

Mr. Ruthven Murray raised a point causing a great deal of thought to oilmen to-day, that of inserting and later possibly altering the depth of tubing while the well was producing through the Xmas tree.

The speaker had not snubbed in tubing under pressure as no blow-out preventers were available at the moment. Nevertheless, he was preparing to run a string of 2 in. upset tubing through a 30 ft. joint of 3 in. heavy pipe set on top of the Xmas tree. He intended making the 2 in. couplings act as pistons in the 3 in. cylinders by placing grummet rings under each coupling. In lowering the 2 in. there would always be one coupling in the 3 in. pipe, and even if the casing head pressure had to be relieved through larger beans, owing to the difficulty of snubbing with tractors, no production would be

lost and the job would be clean. The tubing would be plugged by a cast iron plate held in place by the well pressure and this would be displaced by pumping oil into the tubing (Fig. 6.).

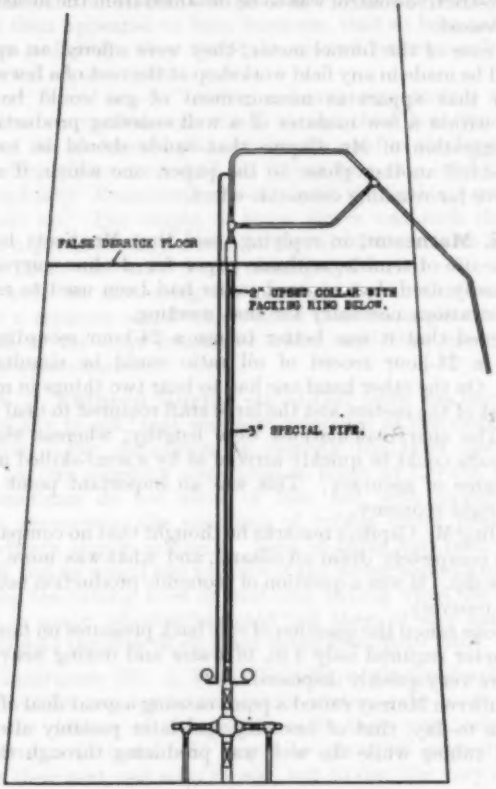

FIG. 6.
SHOWING METHOD OF RUNNING 2-IN. UPSET TUBING THROUGH 3-IN. PIPE.

He had given some thought to the question of plugging tubing to allow of further alteration in depth and he was of the opinion that a piston plug with two catch pawls fitted at the top (Fig. 7) could be pumped down the tubing so that when the pump pressure was relieved the pawls would engage in the gap between the two ends of

tubing in a coupling. After alteration of the tubing depth the plug would be pumped on down either into the hole or into a special receptacle clear of the oil stream. He wanted to carry this idea a step further by pumping down bottom hole beans.

The Meeting concluded with a vote of thanks to the Members of the Apex Club for the use of the club house for the meeting.

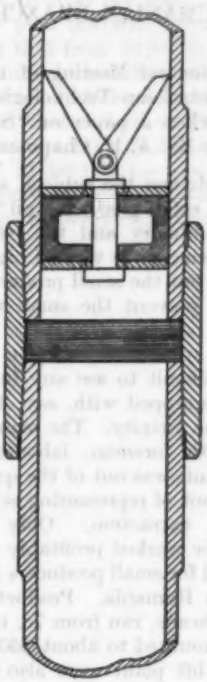

FIG. 7.

RUBBER PISTON FOR PLUGGING TUBING.

Mr. N. Matheson subsequently wrote that he had been successful in snubbing the 2 in. tubing through 3 in. pipe by the method shown in Fig. 6, and that the flow line arrangements on the false derrick floor were as shown in Fig. 3.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

RUMANIAN BRANCH.

THE Twenty-ninth General Meeting of the Rumanian Branch of the Institution of Petroleum Technologists was held at Ploesti on January 30, 1931, when a paper on "Small Well Production Problems" was read by Mr. A. H. Chapman.

The author, in introducing the subject, showed the importance of the great number of small producing oil wells, which constitute the backbone of the industry and the real known oil reserves. Properly controlled flowing wells yielded high returns to producers and gave little trouble, but the small producers called for incessant care and attention to prevent the small margin of profit being turned into a loss.

Under the present system of extreme competition and low prices for oil it was difficult to see any future for small isolated leases, such as those equipped with, say, 4–5-ton producers with no other holdings in the vicinity. The maintenance of a complete lease organisation, with foreman, labourers, shops, warehouse, etc., for such a small unit was out of the question, and such small holdings would not admit of repressuring schemes, gas exploitation and natural gasoline extraction. Only by combining small properties could they be worked profitably as economic units.

Pumping was general for small producers and suitable equipment could be purchased in Rumania. Production costs, exclusive of amortization and overheads, ran from 7c. to 20c. per barrel. The capital expenditure amounted to about $5000 per well.

Compressors for air-lift plant were also procurable locally and production costs are about the same as pumping, but the capital expenditure runs from $8000 to $15,000 per well.

On the hypothetical basis of a lease with twenty wells between 500 and 1500 metres in depth where the oil is partly paraffinous and partly non-paraffinous and there is no gasoline plant or compressors, etc., the following is an estimate of returns. Production plant costs $100,000 and in eight years 2,400,000 barrels of oil might reasonably be anticipated at a lifting cost of 10c. per barrel = $240,000. The total expenditure is thus $340,000. Lease expenses can be taken at $10,000 a year or $80,000 in

eight years, making a total expenditure of $420,000. With an oil price of 75 cents per barrel, the return is $1,800,000 less $420,000 = $1,380,000, against which drilling costs must be charged.

With gas lift at $10,000 per well, the capital expenditure would be $200,000 on twenty wells, and it is estimated that the output under same conditions would be 2,640,000 barrels in five years instead of eight. Running costs would be $264,000 and the equipment would be depreciated 50 per cent. only, so that the total charges are $364,000 plus $50,000 general lease expenses, or $414,000. Subtracting that from $1,980,000, the value of the oil, leaves $1,566,000, against which drilling charges have to be met.

By installing a portable oil absorption gasoline plant at a cost of $40,000, it is estimated that a further $64,250 could be earned, raising the total net revenue from $1,566,000 to $1,630,250, compared with a figure of $1,380,000 for pumping.

The average gas supply of pumping wells is 200 cubic metres per day and the average recovery of gas-gasoline is 180 grams per cubic metre.

Empirical Formulæ for the Production Curves of Oil from Wells.*

By Launcelot Owen, A.R.S.M., A.R.C.S., D.I.C., M.Inst.M.M., F.G.S. (Member).

The question of the mathematical treatment of the curves illustrating the production of oil from commercial oil wells has long been a matter for discussion and attempted solution, and the methods of attack may be divided into two distinct categories.

The first consists in studying and analysing the properties and behaviour of liquids and gases under selected "ideal" conditions, and in applying the results so obtained to the elucidation and correlation of oilfield data. This method has been adopted by S. C. Herold in what is, already, a classical treatise.[1]

The second method consists in taking actual production-time data, deducing from them, empirically, the mathematical formulæ by which they are most closely correlated, and then analysing these formulæ with the object of discovering the significance of the various component factors.

This is the principle adopted in these notes. The writer has confined himself, however, to the consideration of the production of liquid only, although gas curves could be treated in a similar manner.

Two fundamental facts—so obvious that they are apt to be overlooked—may first be considered :—

(*a*) Every oil well that comes in at all has a *finite* initial rate of production.

(*b*) Excluding catastrophic events, the production of fluid (oil *plus* water, etc.) in a well, once started, never ceases *completely*, the so-called "life" of the well being merely a convenient term used to describe the duration of time during which the well yields oil in commercially remunerative quantities.

Any formula adequately describing the known characteristics of fluid production must give therefore :—

(*a*) A *finite* initial value for production at zero time (*i.e.*, when the well is first produced).

(*b*) A *finite* positive value (however small) for any finite time value (however large).

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* Paper received June 1st, 1931.

[1] "Analytical Principles of the Production of Oil, Gas and Water from Wells," Stanford University Press, 1928.

These two conditions exclude hyperbolic equations, if a natural time scale is used, but are met by the exponential expression:

$$P_t = P_o K^t$$

where P_t represents the rate of production t units of time after the bringing in of the well, P_o the rate of production at zero time (initial production), and K a value to be determined empirically.

The actual value of K will, of course, depend upon the particular unit employed in expressing t, but P_t and P_o may be expressed in any convenient unit without affecting the value of K.

It is obvious from the formula that K represents the ratio of the rates of production at the beginning and end of a unit period of time.

Now, the rate of production of oil from a well, *however complicated the conditions may be*, is clearly a direct function of the expulsive force, F, acting upon the oil within the reservoir. Similarly, the rate of production is, also, an inverse function of the resistance, R, offered to the flow of the oil, or, in mathematical shorthand:—

$$P_t = \frac{(f)F_t}{(f)R_t}; \quad P_{t+1} = \frac{(f)F_{t+1}}{(f)R_{t+1}} \text{ and therefore}$$

$$\frac{(f)F_{t+1}.(f)R_t}{(f)F_t.(f)R_{t+1}} = \frac{P_{t+1}}{P_t} = K.$$

It may be noted here that the resistance to flow, R, is not only dependent upon the porosity of the material filling the reservoir, and on the *form* of the channels which allow of the passage of the oil through the reservoir to the well, but is also a function of the viscosity of the oil.

As a first approximation, we may assume that the viscosity of the oil remains sensibly constant over a limited interval of time; and, in the absence of geological catastrophies, so will the porosity of the material filling the reservoir and the form of the channels filling the reservoir.

In such a case, we may write:—

$$P_t = (f)F_t; \quad P_{t+1} = (f)F_{t+1} \text{ and, therefore:}$$

$$\frac{(f)F_{t+1}}{(f)F_t} = \frac{P_{t\ 1}}{P_t} = K$$

It should be noted that the production-time relation is still exponential.

So far, no assumptions have been made as to the nature of the expulsive force, and it has not been attempted to divide wells into separate "controls." One exponential equation has been made to cover the various production characteristics of wells by the variation of the term, K.

The writer has found considerable difficulty in practice in dividing wells into Herold's "volumetric" and "capillary" controls by the use of field data. In fact, it appears highly improbable that a reservoir composed entirely of capillary passages could possibly produce oil in commercial quantities. Viscosity, alone, would surely limit the production very severely. It is freely admitted that the Jamin effect may drive oil out of tight patches of sand into the more open channels within a reservoir, but this is very different from stating that it is the controlling factor. Here, probably, we have the reason for the fact that the only really satisfactory proofs of capillary control have been obtained from gas wells.

Practical Applications of Empiric Exponential Formulæ.

As an illustration, let us first consider actual field data from a well which was produced through a 2 in. flow line. During the period under consideration there were no complications due to beaning, and the well flowed without artificial aid.

The initial production was estimated to be at the rate of 800 barrels a day. At the end of the 4th week, the weekly rate of production was 5425 barrels; at the end of the 11th, 4200 barrels; the 30th, 1575 barrels; the 38th, 1260 barrels; and at the end of the 65th week, 630 barrels.

In a case of this type, where K is obviously less than unity, the labour of logarithmic computation is lessened by substituting C for 1/K, thus:—

$$P_t = P_o K^t = P_o C^{-t}$$

Taking the figures for initial production (rate per week) and for the rate of production at the end of the 4th week, we have:

$$P_4 = P_o C^{-4}$$
$$\text{or } 5425 = 7200 \times C^{-4}$$
$$\text{whence } C = 1{\cdot}066.$$

Similarly, from end of 4th to end of 11th week, $C = 1{\cdot}037$
" " " 11th " 30th " $C = 1{\cdot}052$
" " " 30th " 38th " $C = 1{\cdot}029$
" " " 38th " 65th " $C = 1{\cdot}026$.

The average value of C, from the 4th to the 65th week is 1·036, which may be taken as the characteristic value of C for this well. The divergence from this value in some of the periods may legitimately be explained by allowable errors in estimating production under field conditions. The high value for the first four weeks is probably due to the fact that the initial production was slightly over-estimated.

It is an interesting fact that a majority of the production data analysed by the writer give values for C approximating to 1·035, and it is to be remarked that the variation in this value during the life of any particular well is, usually, small.

Using the value, C = 1·036 for the well under review, we are in a position to calculate its commercial life and flowing production, thus :—

Assuming that the conditions are such that 70 barrels per week represents the low limit of commercial production, and that this limit is reached at time N, we integrate, thus :—

$P_t = P_o C^{-t}$, therefore ΣP_t between the values of P_o and

$$P_N = P_o \int_o^N C^{-t} = P_o \left[\frac{1}{\log_e C} \cdot C^o - \frac{1}{\log_e C} C^{-T} \right]$$

$$= \frac{P_o - P_N}{\log_e C}$$

hence total commercial production by natural flow

$$= \frac{7000 - 70}{\log_e 1{\cdot}036} = 196{,}000 \text{ barrels.}$$

The time value, N, for the commercial flowing life of the well is obtained by substituting the given values in the equation $P_N = P_o C^{-N}$, thus : — $70 = 7000 \times 1{\cdot}036^{-N}$, whence N = 130 weeks, approximately. These values, it may be stated, correspond very closely to the results actually obtained from the well under review.

The total flowing production would be $P \int_o^\infty C^{-t}$

$$= \frac{P_o}{\log_e C} = \frac{7000}{\log_e 1{\cdot}036} = 198{,}000 \text{ barrels approximately.}$$

Although the value of C often approximates, as stated above, to 1·035 (where t is expressed in weeks), different fields, and even different parts of the same field, where the local conditions vary, will give differing values for C. The figure obtained for C, from the production data, moreover, offers a clue to the conditions pertaining within the reservoir and an analysis of the significance of this value will be of interest.

Where C = 1.—In this case the production remains sensibly equal to the initial production and is independent of time, *i.e.*,

$$P_t = P_o C^{-t} = P_o.$$

This corresponds to Herold's " hydraulic control."

If, however, the resistance to the flow of fluid within the reservoir is decreased, by natural channelling or other means, the production will show an increase and, for a period at any rate, the value of C, in the equation $P_t = P_o C^{-t}$, will be *less than unity*, although the expulsive force acting upon the fluid within the reservoir may remain unchanged—*i.e.*, the "control" will still be "hydraulic."

In a similar manner, a tightening of the reservoir material (again without change in the "control") will cause the production to drop and C will assume a value *greater than unity*. If the tightening is progressive, a well under "hydraulic control" may give a production curve which simulates those given by wells under what may be called "gas pressure control," and which Herold classifies as "volumetric" and "capillary."

Where $C > 1$.—This is the usual condition in the vast majority of wells. As has been pointed out above, in many cases known to the writer, C approximates to the value 1·035, but varies in different fields.

Under true capillary conditions, the resistance to flow within the reservoir would be so great that C would tend to approach very closely to unity, thus simulating Herold's hydraulic control, but, under such conditions, it is difficult to conceive that the original production of fluid, within the viscosity range of known crude oils or oilfield waters, could be commercial.

We may now consider an interesting case in which a large initial production, P_o, is coupled with a heavy decline. Such cases, unfortunately, are not uncommon in the history of the oil industry and have been a prolific cause of the loss of capital, as their promising inception has led to unwarranted hopes and expenditure. In such cases, it is often found that the reservoir consists of faulted, non-porous material, the oil occurring along the fault planes. The effective volume of such a reservoir is extremely limited, usually, although it offers comparatively little resistance to flow.

As a matter of experience, it may be stated that a well giving a value of C above 1·07 (t in weeks) is rarely a commercial proposition, and the prospects of the surrounding area must be looked upon with grave suspicion. The first few weeks' production figures will, in most cases, give the necessary information.

Beaning, etc.—If, at any time T, a well is producing at the rate, P_T, and this rate of production is changed to some new value, P'_T, by modifying conditions external to the reservoir (for example, by beaning or by the introduction of air-lift), it is found that C, also, assumes a new value C'.

Had the well been left alone, the total production from time T until the production dropped to the non-commercial value P_N, at time N, would be

$$P_T \int_T^N C^{-t} = \frac{P_T - P_N}{\log_e C}$$

Similarly, under the new conditions, the total commercial production from time T, until non-commercial production, P_N, is reached, would be

$$\frac{P'_T - P_N}{\log_e C'}$$

The formula thus offers a means of judging the commercial advisability (or otherwise) of operations external to the reservoir, according as

$$\frac{P'_T - P_N}{\log_e C'}$$

is greater than or less than

$$\frac{P_T - P_N}{\log_e C}$$

In practice due allowance, of course, must be made for the overhead costs and other considerations dependent on the time factor.

The possibility of forecasting, with fair accuracy, the total production of a well, or a group of wells, provides us, also, with a basis upon which the most commercially satisfactory spacing of such wells may be determined.

There are many other obvious uses to which the formula

$$P_t = P_0 C^{-t}$$

may be applied, and, in the present state of our ignorance of the exact physical conditions existing within oil reservoirs, it is an advantage that the formula treats only with field data and is independent of theoretical considerations.

Decomposition of Ethylene by Heating under High Pressure.*

By H. I. Waterman (Member) and A. J. Tulleners (Student Member).

In a previous publication[1] the formation of gasoline and tar from ethylene at ordinary pressure and without catalysts was studied.

E. Berl[2] has recently carried out similar investigations, and also obtained high percentages of conversion to liquid products.

In the present work it is intended to study the behaviour of ethylene by heating under high pressure.

The ethylene contained 97·5 per cent. C_2H_4 by volume. This was proved from an analysis with bromine water; the dibromide formed by the reaction on bromine, was fractionated after washing and drying it carefully; it distilled almost completely between 129·8 and 130·8° C. The gas-residue remaining after the reaction with bromine amounted to over 6 litres, starting from 306·6 grams of ethylene; this residue consisted almost entirely of hydrogen, methane and nitrogen. A small quantity of unchanged ethylene was also left. The ethylene used in the experiments contained 98·6 per cent. C_2H_4 by weight; higher homologues are not present. Two experiments were carried out in which ethylene was heated under pressure. In the first experiment described (A_2) an autoclave with a capacity of 2030 ml. was filled with ethylene to an initial pressure of 32 kg/cm² at 15° C., rotated and heated slowly to 350° C., at which temperature it remained for 30 minutes.

The final pressure after complete cooling was 32 kg/cm² at 15° C., and the temperature differed little from the initial pressure. Nevertheless some change had taken place, as could be expected from the work of Ipatiew.[3] After the experiment the gas contained 93·8 per cent. unsaturated hydrocarbons, determined by absorption with bromine water, which corresponds with a lowering of 4 per cent. Besides, a formation of liquid had taken place; about 1 ml. of a liquid, volatile at room temperature, separated in the condensation vessels (solid CO_2-acetone) through which the reaction gases were conducted, while in the autoclave, 10 to 15 ml. of a pale brown liquid was formed. The bromine number (McIlhiney) of this

* Paper received April 27th, 1931.

[1] *Brennstoff-Chem.*, 1930, **11**, 337.

[2] E. Berl and W. Forst, Spaltung und Kondensation von Kohlenwasserstoffe, *Z. angew. Chem.*, 1931, **44**, 193.

[3] W. Ipatiew, *Ber.*, 1911, **44**, 2978.

liquid was 55 (addition), the substitution was 15 per cent. bromine by weight (equivalent with the quantity of HBr formed). There was also a slight deposition of carbon on the pyrometer tube and on the autoclave wall. The course of the temperature and pressure with time is shown in Fig. 1. It is evident that some reaction has occurred, but there was no strong conversion.

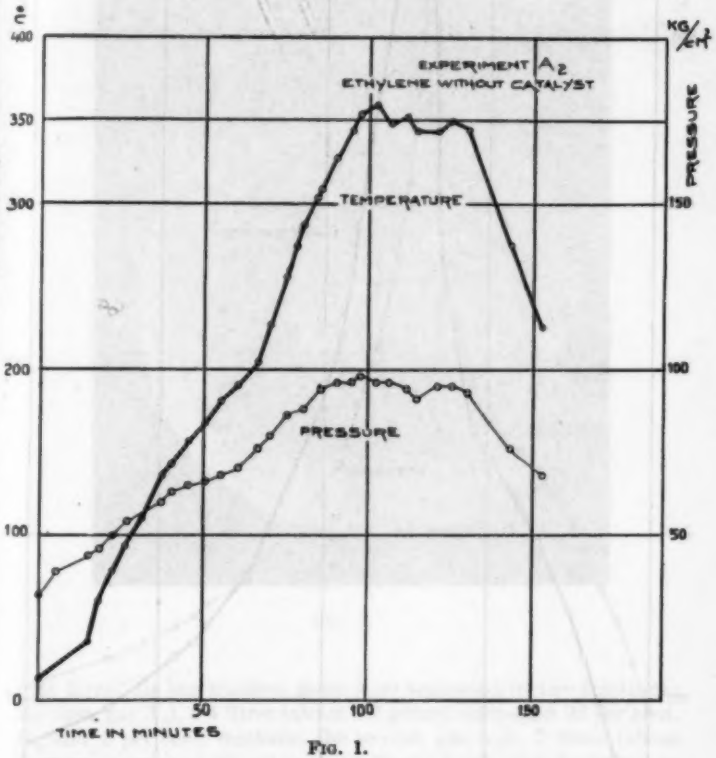

FIG. 1.

Experiment A_3 was carried out under conditions similar to A_2, with an initial pressure of 46 kg/cm² at 18° C. The result was a very strong reaction of an explosive character, which is obvious from the curve in Fig. 2.

At a temperature of about 350° C. and a pressure of 175 kg/cm², both temperature and pressure rose suddenly, the temperature to

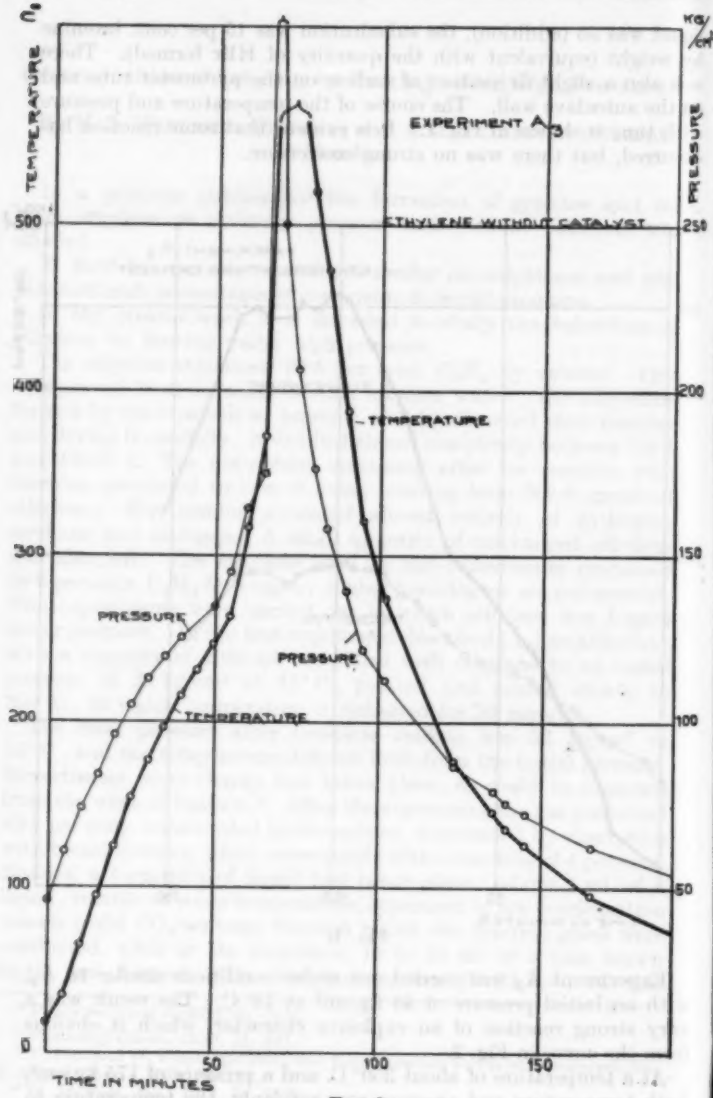
TEMPERATURE °C
PRESSURE KG/CM²
EXPERIMENT A 3
ETHYLENE WITHOUT CATALYST
TEMPERATURE
PRESSURE
PRESSURE
TEMPERATURE
500
400
300
200
100
0
250
200
150
100
50
50
100
150
TIME IN MINUTES

FIG. 2.

above 500° C., the pressure to about 500 kg/cm², at which heating was immediately stopped. The final pressure after complete cooling was 10 kg/cm² at 17° C.; this final pressure is of relatively little importance, as it is quite possible that there was some leakage during the enormous raising of pressure. By fractional condensation

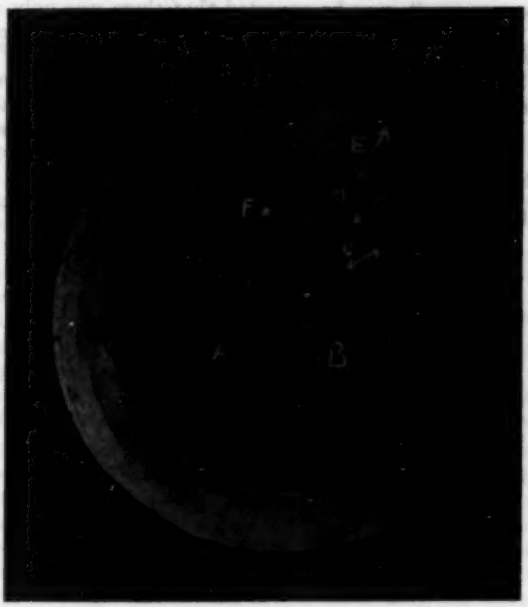

FIG. 3.

with liquid air the reaction gases were separated in two fractions: the first, gas A_2I, 5·4 litres (about 0·8 grams) contained 92 per cent. H_2 and 5 per cent. methane, the second, gas A_2II, 7 litres (about 5 grams) contained 89 per cent. methane, 6 per cent. hydrogen as well as 3 per cent. benzene.

In the autoclave there remained 105 grams of a light compact carbon closely resembling ordinary carbon black, which filled the autoclave entirely. By elementary analysis the carbon proved to contain more than 99 per cent. carbon; it showed absorption power for iodine.

By this investigation it is proved that ethylene at a temperature above 350° C. and under a pressure of about 175 kg/cm² decomposes suddenly, with explosive violence, with the formation of chiefly carbon, methane and hydrogen. The heat liberated by this is considerable, and as a detail of technical importance it may be mentioned that the autoclave need not have suffered by the high temperature and pressure, as it may be expected that there was only a local raising of temperature inside the autoclave where the pyrometer tube is placed.

Fig. 3 shows the contents of the autoclave after the experiment. The greyish contour (E) represents the wall of the autoclave and (D, F, C) the conical and other parts of the wall. A dark grey carbon mass (B) is seen inside with only an opening (A) for the pyrometer tube.

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Injection, Ignition and Combustion in High-Speed Heavy-Oil Engines.*

By S. J. Davies, Ph.D., M.Sc., and E. Giffen, M.Sc.

The subject of the high-speed heavy-oil engine is treated under two headings: processes in the fuel injection system and processes within the engine cylinder.

Processes in the Injection System.—Under the first head, the main point stressed is the effect of fuel compressibility and of pressure waves set up in the injection line by the motion of the pump plunger. Data on compressibility obtained by various investigators are given to show the magnitude of the effect. A mathematical analysis is developed of the pressure-waves set up in the line during, and subsequent to, the pump plunger stroke. The analysis gives a measure of the effect of increased length of fuel line in increasing the injection lag, delaying cut-off, and in increasing the tendency to give secondary injection and dribbling. Open nozzle injection is condemned except on grounds of simplicity. The high degree of mechanical perfection and durability of the modern fuel pump were commented upon, and an illustration given of the behaviour of a Bosch pump before and after long service.

Processes in the Engine Cylinder.—After a brief indication of the work of various investigators on the factors influencing the penetration of fuel sprays, a detailed discussion is given on the "Ignition Lag" and the subsequent rate of pressure rise in a compression ignition engine. Neumann's work is cited and some of his indicator cards reproduced to show the effect of engine design on this lag. From these it is inferred that, the more rapid is the relative motion between air and the fuel particles, the more rapid will be the rate of heat transfer and the less the lag. Similarly, the greater the temperature difference between air and fuel and the finer the atomization, the less the lag. When different designs of engines are considered, however, the rate of pressure rise is not necessarily determined by the duration of the lag. Since a high average rate of pressure rise increases the thermal efficiency

* Précis of paper read on March 31st, 1931, before a Joint Meeting of the Chemical Engineering Group, the Diesel Engine Users' Association, the Institute of Fuel, the Institute of Marine Engineers, the Institution of Automobile Engineers, the Institution of Engineers-in-Charge, the Institution of Mechanical Engineers, the Institution of Petroleum Technologists, the Junior Institution of Engineers, the Royal Aeronautical Society and the Society of Engineers.

but increases running roughness, it is concluded that the best compromise is to decrease the ignition lag. This will allow the average rate of pressure rise to be less rapid for a given maximum pressure point in terms of crank angle. In addition to the effect of design in obtaining this desired reduction in lag, the influence of the nature of the fuel and the effect of dopes on lag is indicated and research on these lines is called for.

DISCUSSION.

[The following suggestions and points of interest have been selected from the discussion.]

Dr. Ormandy suggested that analysis of samples from an engine cylinder during the delay period would help to elucidate the processes occurring during the ignition lag.

Mr. J. Calderwood was of the opposite opinion to the authors with regard to open injection nozzles. He considered that it was easier to design an open nozzle without dribble than a fuel valve without dribble.

Mr. W. A. Tookey suggested that the main interest of academic research was in giving an explanation of why certain things were already working in practice. A study of the problems which confronted the engineer in the early days of the gas engine would be invaluable in the development of the high-speed heavy-oil engine.

Major G. P. Bulman gave some details of the performance of a Junkers aero engine during a recent test. The engine developed 720 H.P. and had an overall weight of 1800 lb. The fuel consumption was 0·37 lb. per B.H.P./hr., with a lubricating oil consumption of 0·03 lb. per B.H.P./hr. An altitude of 20,000 ft. had been attained with this engine. An American Packard engine, tested over here, had given disappointing results. The following criteria of satisfactory performance were accepted by the R.A.F. : 100 lb. B.M.E.P. at 2500 R.P.M., fuel consumption not more than 0·40 lb. per H.P. and maximum pressures of 800-850 lb.

Mr. L. Le Mesurier pointed out that the figures given by the authors for pump leakage before and after service needed to be treated with reserve as no mention was made that the fuel viscosity was the same in both tests.

With regard to the need for research on fuel characteristics, he would refer the authors to a paper by Mr. Stansfield and himself, recently given before the I.P.T. Fourteen fuels had been examined in four different types of engine, and the effects of fuel nature on

ignition lag and running noise had been investigated. It was found, almost invariably, that increased ignition lag was accompanied by greater roughness and that fuels could be roughly classified, as regards shock, by comparing the petrols produced from the crudes. Those giving the most anti-knock petrols gave the roughest running Diesel fuels and vice versa.

Mr. Cook maintained that, contrary to the view expressed by the authors, smoothness or roughness of running did not depend on the *mean* rate of pressure rise from the first breakaway from the compression line up to the maximum point. A low initial rate of pressure rise, even though followed by a high rate and a high maximum, was smoother than a uniform rise, of the same amount over the same crank angle. This desired low initial rate could be obtained by indiscriminate turbulence, whereas a uni-directional swirl tended to give a more uniform rate and rougher running.

Mr. A. L. Bird had found that, in his experiments on the effect of turbulence on the ignition of oil sprays in closed vessels, the excess air ratio had a very pronounced effect on lag. Above 4/1 ratio, the lags were very high whatever degree of turbulence was induced. At 3/1 excess air ratio, at temperatures and densities similar to those in an engine, the ignition lag was only about 0·004 sec., without turbulence.

Mr. Alcock pointed out that the effect of pressure waves in pipe lines was lessened in practice owing to variations in cross-section. Such waves could roughly be damped out by an unloaded non-return valve near the pump end of the line. In practice the performance of an engine, with either type of injection, was practically identical in spite of a slight dribble with the open type which usually lasted over a couple of degrees at most. Carbon formation on the nozzle was a more serious disadvantage, but this only occurred in engines with a low degree of turbulence near the nozzle.

Mr. Strube stressed the value to the designer of data on fuel compressibility over a range of temperatures and pressures.

Mr. Wood had found that the substitution of steel for copper in the fuel piping used in the tests of a certain pump had smoothed out the pressure steps observed in the discharge line. He suggested that the different extensibilities of the two materials might account for this.

Mr. S. W. Nixon agreed with the authors in disliking the open type of nozzle, particularly for vehicle engines. Apart from the danger of dribble and secondary discharge due to pressure waves, it was difficult to adjust the orifice area so as to obtain good atomization at idling speeds without necessitating unduly high

line pressures under full load and speed conditions. A further point of interest was the effect of orifice discharge co-efficient on fuel consumption. Data was available showing that a high co-efficient led to increased consumption. This, he believed, was due to unsatisfactory atomization, which was associated in some way with low energy loss in the transformation of pressure into kinetic energy.

Mr. C. B. Dicksee observed that the effect of long ignition lag in inducing rough running was due to the increased proportion of fuel in the cylinder when combustion started. He also pointed out that an advance in injection timing increased the lag owing to the lower compression temperature and density at the moment of injection.

Wing-Commander Cave-Browne-Cave suggested that a careful examination should be made of the effect of pre-heating the inlet air on the lag with a given fuel.

CURRENT PETROLEUM NOTES.

Benzine from Turner Valley Gas.—Experiments being carried out at the Institute of Technology, Calgary, indicate that a production of 1,500,000 barrels of benzine may eventually be obtained from Turner Valley natural gas. An experimental plant producing about 5 gallons benzine daily will be operated for one year, after which the production of a large commercial plant will be considered.

New Refineries in Canada.—A refinery having a rated capacity of 12,000 to 15,000 barrels of crude per day is being built by the British American Oil Co. at Montreal East and is expected to be ready for operation before September 1. A refinery is shortly to be established at Moose Jaw, Saskatchewan, with a daily capacity of 400 barrels of crude.

Cracking Plants in the U.S.A.—The total charging capacity of cracking plants in the U.S.A. on January 1, 1931, was 1,950,781 barrels per day, an increase of about 14 per cent. over the previous year. Of the total capacity, 82 per cent. was in operation, 12 per cent. was inoperative and 6 per cent. under construction. The total number of units was 1868.—*U.S. Bur. Mines Information Circular* 6509.

Properties of California Crudes.—The physical and chemical properties of eight crude oils from the deep-seated sources in the Kettleman Hills, Elwood, Plaza del Rey, Inglewood and Santa Fé Springs fields of California have been determined. The paper includes a short discussion of results, tables of data and individual analyses.—*U.S. Bur. Mines Report of Investigations* 3074.

REVIEWS.

A Monograph of Viscometry. By Guy Barr, B.A., D.Sc. London: Oxford University Press. 1931. Pp. xiv.+318. 30s. nett.

Dr. Barr is eminently qualified from his long experience of the subject to discuss the development and the technique of the Measurement of Viscosity.

It is rather surprising, in view of the considerable extent of the scientific literature dealing with viscosity, there should be so small a number of text books devoted to this important subject. The classical work of Brillouin is mainly concerned with the development of the complete mathematical treatment of the internal friction of fluids. Dunstan and Thole's "The Viscosity of Liquids," Bingham's "Fluidity and Plasticity," and Hatschek's "Viscosity of Liquids" are indeed the only available monographs.

The author points out that these books, to which reference has been made, are generally concerned with the connection between viscosity and molecular structure, whilst the methods of measurement have in general only been briefly discussed, and therefore there was a definite need for a book devoted entirely to viscometry.

After the general discussion of the viscous flow of fluids in tubes, in which the fundamental and classical work of Poiseuille is discussed, together with various corrections that have been worked out by Couette, Riemann and Reynolds, the author proceeds to the development of the absolute viscometer and the exact methods of its manipulation.

Next he deals with commercial viscometers, including those of Redwood, Saybolt and Engler. He points out that the vast majority of determinations in the literature have been made with capillary viscometers for relative measurements, most of which are, in effect, modifications of the well-known Ostwald type. In connection with the natural development from this work of methods for determining the viscosity of gases, Rankine's work is described in some detail.

The falling sphere method that has been found so valuable for the determination of the viscosity of such materials as cellulose derivatives is described, and methods based on rotation and oscillation, such as those of Hatschek, MacMichael and Searle, are discussed.

Some of the less known methods, like that of Trouton, in which the deformation of a rod under its own weight, or a lead wire under a particular stress, and the twisting of a cylindrical rod, give a completeness to the whole treatment, and afford the experimenter a wide choice of laboratory methods.

A very interesting chapter comes at the end of the book, and is concerned with the study of anomalous systems, such as colloidal solutions and suspensions. In this section is to be found an account of the important work of Bingham.

The book is most admirably produced and illustrated, and will be entirely indispensable to the physical chemist. A. E. Dunstan.

The Examination of Fragmental Rocks. By Frederick G. Tickell. London: Oxford University Press. California: Stanford University Press. 1931. Pp. x.+127. $5.

The volume is a concise account of the physical and mineralogical characters of fragmental rocks.

It really consists of two sections, which deal firstly with such properties as grading, porosity and permeability in sediments, while the second section s devoted to crystallography and mineralogy.

The first chapter, dealing with size analysis, discusses the rounding of mineral particles and the grading of sands, etc. Its discussion of sieving and water classification is quite adequate but it curiously fails to give any clear statement on elutriation. The chapter on porosity and permeability is an excellent general statement of the case, and, on the whole, the first four chapters of the books are models of terseness and clarity.

It is questionable whether it is necessary, for the sake of making the treatise self-contained, to add chapters five and six on the identification of minerals. The optical and physical properties of the latter are independent of whether they are present as separate grains in a sediment or as crystals and fragments in an igneous or metamorphic rock. To be sure, there are such secondary features as rounding, etc., but in view of the number of excellent treatises on crystallography and mineralogy it hardly seems necessary for the sake of completion to include a short and therefore inadequate description of the minerals to the present treatise.

With this one reservation the book can be thoroughly recommended as a concise account of the subject, and will be very welcome to students. The author has made abundant use of illustrations and diagrams, which add to the terseness and clarity of the exposition. V. C. Illing.

The Oil Exploration Work in Papua and New Guinea Conducted by the Anglo-Persian Oil Company on Behalf of the Government of the Commonwealth of Australia, 1920–1929. Four volumes, quarto, illustrated and with numerous coloured geological maps and sections. London. 1931.

The anxiously awaited report of the Anglo-Persian Oil Company on the results of the geological surveys carried out by it on behalf of the Commonwealth Government in Papua and New Guinea has now been published and fills four large quarto volumes of text and two of maps. That this mass of material should have been assembled and published so quickly is a tribute to the energy of its editor, Mr. B. K. N. Wyllie, M.A., B.Sc., F.G.S., F.R.G.S., M.Inst.M.M.

The first volume opens with a foreword by Sir John Cadman, Chairman of the Anglo-Persian Oil Company. This is followed by an historical outline by B. K. N. Wyllie, reports of the First Geological Expedition, 1920–1923, by various authors, and drilling operations at Popo, 1922–1929, by B. K. N. Wyllie.

Volume 2 consists of reports of the Second Geological Expedition, 1927–1929, Oriomo, Cape Vogel, Barum River, Sepik, Hansemann Coast, by various authors.

Volume 3 contains the reports of the Second Geological Expedition, 1927–1929: Finsch Coast, by J. Nason-Jones.

Volume 4 contains a Contribution to the Tertiary Geology of Papua, by J. N. Montgomery; A Brief Review of the Oil Prospecting Work at Upoia, 1911–1920, by J. N. Montgomery; and last, but by no means least, A Critical Study of the Geology and Oil Prospects of Papua and New Guinea as Revealed by the Work of the Anglo-Persian Oil Company, 1920–1929, by B. K. N. Wyllie.

Volumes 5 and 6 consist of maps and sections admirably executed and reproduced in colour.

The whole report forms one of the very great contributions to geological literature in recent years and reflects great credit upon all concerned in its production. Unfortunately, for many reasons, its very excellence results in its being very costly and the published price amounts to £10, which puts it out of reach of most individuals and institutions.

Those portions of the report dealing with the highly complex geology of the two territories are technical in character and will therefore not have a very wide appeal. While it is clear that our present knowledge of the geological structure is quite rudimentary and that infinitely more study is necessary before theories can be set upon sure foundations, the problems are attacked fearlessly, though with commendable restraint, and tentative explanations are put forward. As is only to be expected in the circumstances, it is necessary, in many cases, to suggest alternative hypotheses and to leave it to the future to decide whether any of them are completely satisfactory. That there should be marked differences of opinion in many matters is only to be expected and parts of the work will not be accepted in this country without criticism, and, it is devoutly to be hoped, without much supplementary investigation.

It is necessary to refer especially to the masterly treatise by Mr. Wyllie, which forms the culmination of the entire work. This reaches the high water-mark of critical geological discussion and is at once concise and clear.

Naturally, for most people in Australia the burning question is "What hopes of obtaining oil are held out by the investigations?" The reply is disappointing in the extreme. The report is almost completely damnatory in this respect.

In the "Foreword" Sir John Cadman says:—

"It will be clear, from a study of these six volumes, that much valuable work has been done and that a very wide field of research has been covered, often in the face of great physical obstacles, and, unfortunately, without the encouraging stimulus of successful discovery. The acquisition of positive knowledge has necessarily been very gradual; early theories have been invalidated as the field of investigation widened, and, in general, the evidence as it accumulated tended not only to throw into relief the complexities of Papuan geology, but also, in doing so, to eliminate the early hope of large possibilities and quick results.

". . . Geology is not an exact science and it may be that certain of these views will be challenged. Provided that this is done on the same level of knowledge and logic as the case presented by him, nothing but good can result; but it is clear that, at the best, much more work remains to be done, and more positive and more favourable evidence than is yet available needs to be obtained, before an optimistic case can be presented before facing large expenditure on actual exploitation work. The conclusions at which Mr. Wyllie arrives—with which, on the evidence presented, I see no reason to disagree—must therefore stand as authoritative and well-informed opinions until, and unless, they are contradicted by new research and discovery."

In his admirable critical review Mr. Wyllie points to the analogies of the oilfields of the East Indies and indicates that, in these areas, the *productive* oilfields are confined to the newer Tertiaries (Neogene). In both territories the structures in rocks of this age are believed to be too much eroded and too fragmentary to hold out much hope of success.

It is believed that the chances of finding more than traces of oil in the older tertiaries are small.

Mr. Wyllie's reasoning is close and logical, and must be accepted as a very serious setback to the hopes which have been held out of successful oil search in New Guinea.

If a criticism can be levelled at these conclusions it is that they are founded upon very sharply defined theory, which, though very plausible, has not as yet been proved up to the hilt. Admittedly also, analogies between oilfields are apt to be somewhat dangerous. So many factors enter into the question

that each area constitutes a problem in itself and must be examined individually. That Mr. Wyllie recognises this is shown by his frequently reiterated advice that much more preliminary research should be undertaken in that part of New Guinea which is under Australian jurisdiction before any deep drilling campaign is begun.

If only Australians will take this advice to heart and carry it into execution success may come eventually, and, in any case, knowledge will be gained, public confidence maintained and, ultimately, money will be saved. The squandering of funds on a spectacular but ill-advised drilling campaign must be prevented at all costs.

His final summary of the position must be quoted *in extenso* to indicate the conclusions arrived at.

He states :—

"This review ends, therefore, with a note of pessimism. Some possibilities have been admitted, in regions not yet fully (or even partially) explored, but in the main the hopes entertained by the earlier geologists have been rejected.

"Some part of this contradiction may be attributed to the changeableness of geologic theory, which at the moment is undergoing a rapid evolution. Most of it, however, is due to a difference of practical outlook. In 1920–1921 structural geology was in complete control; all that geologists were required to do was to locate anticlines with adequate drilling depth of sedimentary rocks; common sense was supposed to be quite competent to mark out the regions to which oil-exploration should be directed; the geologist, then, was expected to get busy and to do his stunt in time for the drilling equipment that was already on the way. *Tantum petroleum potuit suadere malorum.*

"At the risk of tedious repetition it must again be said that in 1921 a location on the Popo Anticline was quite in accordance with current oilfield practice. Ideas regarding a facies of oil formation were then scarcely embryonic. Anticlinal structure was in complete ascendancy, and could point to a whole series of triumphs, which constituted a strong empirical claim to reliability. Nothing succeeds like success.

"Nevertheless, even apart from the difficulty of drilling through flowing mudstone, which might possibly be overcome eventually by developments in drilling technique, the Popo location cannot any longer be regarded as enjoying the full support of geological authority. On the contrary, comparison with the nearest and most analogous oilfield regions, and reference to some of the most modern views regarding oil formation, tend to induce the belief that prospects of anything more than a slight, doubtfully economic oil-production at Popo and similar structures are exceedingly poor.

"Mistakes of the past, however (and the history of oil-exploration is full of them), provide the most valuable lessons for the future. It has to be realised, in the first place, that prospects for the finding of substantial oilfields in Papua or New Guinea must—on the basis of the Anglo-Persian work, which has touched on most of the regions that cannot immediately be ruled out of the question—be pronounced rather remote; and, consequently, that oil-enterprises would be well advised to adopt an extremely critical attitude towards proposals to incur the great expense of drilling before geological research has had opportunity to check and recheck stratigraphic and structural data over the widest possible field.

"It is considered absolutely imperative that a full programme of laboratory work (micro-palæontology and petrography) should be carried on in conjunction with field work, as the sole means of ensuring that correct stratigraphic detail which is the only foundation for correct facies and structure-interpretation and accurate palæontographic reasoning.

"It is readily admitted that this is a reversal of the common order of events by which oilfields have been found, since the stimulus of a discovery-well has usually been necessary to promote the introduction of such refinements of geological technique. However, the example of the Government of the Dutch Indies in instituting extensive geological researches in Sumatra, which were largely responsible for the discovery of many of the oil-bearing anticlines of Palembang and Djambi, may be offered as a satisfactory precedent.

"The writer, finally, desires to record his opinion that the search for oil in Papua and New Guinea could be approached most satisfactorily if it were regarded as only part of a scheme of systematic research into the geology and mineral resources of the territories by a properly equipped geological survey department or departments, maintained jointly or separately by the two Governments, on the plan of the British Colonial geological surveys—or the Mijnbouw in the Dutch Indies.

"If, however, it is still considered essential to give to oil precedence over all other minerals, fresh starting points from which research would appear likely to obtain valuable clues are here summarised and indicated on a small scale map (Fig. 5). These are:

"(1) The belt of country north-west and south-east of Nalopo Island in the Purari River, the sharply folded hill country to north-east and the swamp region to south-west (which may be less extensive than is shown on existing maps, and may possibly yield topographic structure-clues).

"(2) The southern coast of Goodenough Bay and the Ruaba Valley.

"(3) The middle Ramu Valley, in the region of the Arumene Hills; and

"(4) The country on the south side of the Torricelli Range, wherever best approachable."

W. G. WOOLNOUGH.